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TECHNICAL COLLEGES AND INDUSTRIAL RESEARCH

IN his paper "Industrial Research and the National Economy" at the Midland Regional Conference of the Federation of British Industries on March 25, Sir William Larke stressed the important part which the technical colleges of Great Britain should play in the conduct of technical research. Mr. F. E. W. King, in a review of the Midland research organisations at the same Conference, commented on the comparative neglect of research by the technical colleges in the past, and suggested that the implementation of the recommendations of the Percy Report on Higher Technological Education should do much to remedy this position. More recently, at the Scottish Regional Conference of the Federation of British Industries, on April 25, Dr. W. M. Cummings also referred to the assistance which the technical colleges could give to industry, both in the way of technical research and in consulting work.

Dr. Cummings went on to urge the need for closer contact and better mutual understanding between the technical colleges and industry in Britain, and although his remarks related more particularly to chemical industry in Scotland, it is clear from the report on "Industrial Research in Technical Colleges", to which Sir William Larke referred in his paper at Birmingham, that much of what Dr. Cummings said is true of all subjects and throughout Great Britain. This report, by a special sub-committee of the Industrial Research Sub-Committee of the Federation of British Industries which was appointed "to consider the results of a survey on the industrial research activities of Britain's technical colleges and the Ministry of Education's future plans for industrial research in technical colleges; to report on the possibility of co-operation by industry and the form such co-operation might take", shows that, of the fifty-seven technical colleges selected from approximately two hundred by the Ministry as likely to provide positive answers, thirteen were not carrying out research, twenty-nine, including the majority of the senior technical colleges, were carrying out some research, and in only fifteen colleges were more than five persons engaged in research. About ten of the colleges possess special equipment of value for industrial purposes; all have close links with industry, and all but two possess satisfactory libraries. About 250 research workers, of whom about 160 are staff, were reported in the returns in this category, as against 72, of whom 52 are staff, in the returns from the twenty-five colleges in the second category.

The overall picture gained from the survey of the most active colleges is one of progressive development, handicapped by inadequate facilities and equipment, and by lack of staff. Moreover, in only seven of the fifty-seven colleges questioned do research scholarships exist, although there are grants from the Department of Scientific and Industrial Research to individual investigators and a few endowments from industry. Again, where there is close contact with local industry, it is normally through heads of departments, who act from time to time in

a consultant capacity. Frequently, testing for local industry is carried out by technical colleges, often with specialized equipment for the purpose. Development work in assisting in the application of the results of research is limited mainly to the special war-time requirements of local firms, and contacts with the research associations and the Department of Scientific and Industrial Research are limited and spasmodic.

Commenting on the position revealed by the survey, the Sub-Committee, which consisted of Sir Robert Pickard (chairman), Dr. W. T. K. Braunholtz, Sir Arthur Fleming, Mr. Edward Meigl and Dr. B. J. A. Bard as secretary, considers that the amount of research carried out, and the extent to which the technical colleges are assisting local industry in the way of research, development or advice, are inadequate when measured either in terms of the resources and potentialities of technical colleges or the requirements of industry. Moreover, it holds that industry is not, and has not been, made sufficiently aware of the facilities that exist in technical colleges, or the assistance they can provide in the solution of industrial problems and in the application of scientific knowledge for the benefit of local industry. More particularly, since the imparting of knowledge cannot be separated from its advancement, if teachers are to maintain their enthusiasm, and the right type is to be attracted to the profession, the Committee urges that opportunity for research by the teaching staff should be a *sine qua non* in all senior technical colleges, and that opportunity should simultaneously be provided for graduates and students to participate in original investigations related to local needs and interests.

On the scope of such research the Committee recognizes that the primary responsibility of the technical college is to train men for technical positions in industry, and that accordingly any research prosecuted should bear some relation to this objective. The training of men for research posts in industry, however, is not necessarily outside the function of the technical college; and on the other hand, carrying out industrial investigations may assist members of the staff of the technical college to keep up to date in their knowledge of industrial practice and thus relate their teaching more closely to industrial needs. So far as long-range fundamental research is concerned, the Committee believes that such research is best carried out at a university or independent institution, or by an industrial research association; although on occasion such investigations may be suitable for technical colleges if they are adequately staffed and equipped.

As to actual research for local industry, the Committee endorses the views expressed by the Ministry of Education last year in Circular 94; but it suggests that investigations of which a manufacturing concern offers to bear the full cost, with a proviso prohibiting or restricting publication of results, should be considered with regard to the possible benefit to the college. Similarly, in regard to consultation with local industry, the Committee endorses the principles laid down in the statement "Principles suggested for a Code of Practice in respect of consulting and similar work accepted by members of whole-time academic staff" which was approved and issued last year by the Board of the Institute of Physics and the Council of the Royal Institute of Chemistry.

The Committee believes that the plans for encouraging research in the technical colleges outlined in the Ministry of Education's Circular lay a sound foundation, and most of the colleges have plans in hand for expanding their research effort. It is, nevertheless, considered that industry can contribute to the success of research work at technical colleges, and that this in turn will benefit industry itself. Industry should take increasing interest in the technical college, not only as a place where staff can be trained, but also as a centre which may be of supplementary assistance to the research activities of the industry and the private consultant in the solution of both general and particular industrial problems. Accordingly, the report recommends that industrial concerns with their own research departments should, wherever possible, place research work with their local technical college, and consult the college when an outside opinion or specialized advice within its competence is required. They should also provide financial help and equipment where required, to increase the capacity for service to industry, arrange for interchange of staff, for vacation and refresher courses and works visits from time to time, encourage the organisation by the college of a reference library and information service related to its field of activity, and generally develop the closest possible relations for their mutual benefit, including active participation on the governing body.

Each trade association should ascertain which technical colleges in Great Britain can be of assistance to the industries it represents, and should assist financially in the provision of equipment or personnel where necessary, as well as maintain contact with regional education councils and local education authorities.

The Industrial Research Secretariat of the Federation of British Industries, the Committee suggests, may well play a constructive part in bringing industry and technical colleges into closer contact for the solution of industrial problems; and the two regional conferences which the Federation has organised since this report was signed are steps in the right direction. The Secretariat can act to some extent as a clearing house, though the Intelligence Division of the Department of Scientific and Industrial Research should be equally effective, and care should be taken to avoid overlapping and duplication of effort. The Federation's Industrial Research Secretariat would rightly welcome any approach from a technical college to obtain information or make research or industrial contacts, or with regard to the initiation of staff exchange schemes; indeed, there should be a wide field in which there is little risk of duplicated effort. Moreover, the appendix (dated January 1, 1947) listing technical colleges with research activities and facilities likely to interest industry indicates that in the way of information

much co-operative effort is still required to fill the gaps in systematic knowledge.

The information in this list was supplied by the Association of Principals of Technical Institutions. It is somewhat fuller than that contained in the lists of industrial research in technical colleges and at the universities appended to Mr. J. G. King's paper on Midland research organisations read at the Midland Regional Conference of the Federation last March, which was derived mainly from the Federation's own records or from the "Notes on Current Scientific Researches in the United Kingdom" prepared for the Royal Society Empire Scientific Conference last year; but neither list is complete, and the approval with which the "Notes" were received at the Empire Scientific Conference shows how warmly such an authoritative and comprehensive compilation would be welcomed. Naturally it could never be entirely up to date, but if maintained by the appropriate bureau it should do much to assist contact between industry and the technical colleges and also the universities, and especially to help the technical colleges to plan their own research.

The report of the Federation of British Industries Sub-Committee is chiefly of value as indicating the approval by an important section of industry of certain current trends of opinion in educational and professional opinion, as reflected, for example, in the Ministry of Education Circular and in the Code of Practice issued by the Joint Council of Professional Scientists; but beyond showing that the Federation is aware of the possibilities of the educational work it could undertake in promoting contact between the technical colleges and individual firms, and that it is prepared to use those opportunities to the full, the report contains little in the way of constructive proposals. Moreover, there are some important omissions. There is no reference to recent developments, such as refresher courses, which can indeed prove as valuable to the teacher in the technical college as to the staff of an industrial firm. The Joint Research Council established in Manchester, too, may well become, as Dr. W. H. Cummings suggested at Glasgow, the prototype of what is required in other regions to facilitate contacts between both technical colleges and the universities and local industry.

On the proposals of the Percy Report on Higher Technological Education the Committee makes no comment, and its survey of the relations between technical colleges and the universities seems to be somewhat superficial. The Percy Committee missed an opportunity when it concerned itself exclusively with the needs of engineering and failed to compare the needs and experience, for example, of the engineering and chemical industries, and the present report takes rather too narrow a view of the training of the staff in the technical colleges. The only really satisfactory way for such teachers to keep up to date in the industrial technique of their particular subject is for the teacher to return to industry for substantial periods. The conduct of subsidized *ad hoc* investigations for industrial firms in the laboratories of a technical college is unlikely of itself to meet that need, yet the report gives no indication of the views of the Committee as to how such interchange should be encouraged. Satisfactory as the report may be so far as it goes, and rightly as it emphasizes the opportunities for research which the technical colleges could offer, on the whole the Committee has approached the subject too timidly, and has failed to define sufficiently clearly the relative functions of the universities and technical colleges; it has overlooked the importance of free interchange between the technical colleges and the universities, and between both these and industry, and has confined itself to the general point that research could be carried out more extensively at the technical colleges, without indicating the character of the investigations which it is reasonable to expect the technical colleges to be equipped to pursue. There is little attempt to define clearly the conditions on either side for closer co-operation. By contrast, Prof. Edmund Giffen's inaugural lecture at Queen Mary College, London, on "Engineering Research in the University" (Oxford University Press, London, 1946. 1*s.* 6*d.* net) is marked by clear thinking on fundamental aspects. One would have welcomed comments from the Federation of British Industries' Sub-Committee on Prof. Giffen's suggestions, and more particularly on the scheme he proposes for co-operation between the universities and research associations. Such a scheme should be equally applicable to the technical colleges and to fields other than that of engineering; but the inherent weakness of the research association movement itself renders further industrial contact essential if the technical college is to reap the full benefit of intimate contact with the most recent advances in industrial practice and technique. Here the joint research council on the lines of that at Manchester might contribute something, and it is to be hoped that the promised report from the Parliamentary and Scientific Committee on schools and colleges of technology in Great Britain in relation to scientific and technical man-power will take the matter a stage further, and deal more imaginatively and constructively with these important questions.

NEW LIGHT ON VESALIUS

A Prelude to Modern Science

Being a Discussion of the History, Sources and Circumstances of the "Tabulae Anatomicae Sex" of Vesalius. By Charles Singer and C. Rabin. (Publications of the Wellcome Historical Medical Museum, New Series, No. 1.) Pp. lxxxvi+58+6 plates. (Cambridge: At the University Press, 1946.) 45*s.* net.

DR CHARLES SINGER has celebrated his seventieth birthday by the publication of one of his most important contributions to the history of science. The works of Vesalius have attracted more attention, and have been more intensively scrutinized, than those of any other anatomist, and it might well be thought that there was nothing more to be said. It is true that we still await an English translation of the "Fabrica", but even this monumental and baffling task is approaching completion in the United States. Now Dr. Singer has raised Vesalian commentary to so erudite a plane that his

successors must perforce master the technique of the higher criticism if their labours are to command attention and respect.

In this work Dr. Singer has secured the collaboration of Dr. C. Rabin—a name new to students of the history of science. He is assistant to the professor of Arabic in the University of Oxford, specializing in comparative Semitic philology, and the contribution to the volume of such a scholar obviously adds much to its content and importance. Dr. Singer himself, however, has devoted many years to the study of Latin anatomical and medical terms which had a Semitic origin. The plan of this "Prelude to Modern Science" includes the following sections: (1) character and purpose of the "Tabulae Sex", printed in 1538; (2) Vesalius and the schools of Louvain and Paris; (3) Italian predecessors of Vesalius; (4) Galenic physiology and its Latin presentation; (5) certain anatomical elements of the Tabulae (for example, reliance of Vesalius on animal anatomy, rete mirabile, etc.); (6) Renaissance anatomical vocabulary; (7) Semitic elements in the Tabulae; (8) translation of and commentary on the Tabulae; (9–12) general, Greek, Arabic and Hebrew indexes and reduced facsimiles of the six plates of the Tabulae.

The authors regard the "Fabrica" of Vesalius, published in 1543, as "the first great achievement of modern observational science. It opens a new scene as with the quick rise of a curtain, for it is suddenly, essentially and brilliantly modern—modern in appearance, modern in outlook, modern in method, modern in its art and in its technique. And modern, too, in what it omits no less than what it includes. It is a startling apparition in the very midst of that imitative world of the revival of classical learning which still pervades its language." Yet the Tabulae Sex, printed only some five years earlier, is quite different in outlook, and is inspired by Galen and medieval tradition even to the extent of grafting the rete mirabile of an ungulate on to the arterial system of man. The explanation of this contrast constitutes a 'Vesalian problem', of which the authors produce a convincing solution. They point out that by the sixteenth century medicine was deeply committed to the acceptance of hypothetical entities "the separate existence of which no one could verify and, therefore, no one would deny". It had become, indeed, highly astrological. A very young man such as Vesalius was at the time could scarcely fail in his early work to be influenced by current obsessions; but his reaction to the call of factual anatomy, as embodied in the later "Fabrica", "gave in a trice a new and far more positive basis to medical thought. In the course of a very few years medicine was to become anatomical. Observational science was thus born with the shortest of birth pains."

One of Vesalius' most inspiring successes was his exploitation of the graphic method of teaching anatomy, and if he did not initiate this method he was the first to demonstrate that it was an indispensable adjunct to the study of animal structure. It is generally accepted that the figures in the "Fabrica" were the work of Calcar, a pupil of Titian. The present authors agree that the three skeletons of the Tabulae "are certainly by Calcar", but that they compare so unfavourably with the corresponding figures of the "Fabrica" that it is "unlikely" that Calcar played more than a minor part in the illustration of that work. "With these plates [of the Tabulae] Calcar effectively disappears from the anatomic scene, nor does he, in doing so, shroud himself in a cloud of glory." It is suggested that the artist of the "Fabrica" "was a young man, unknown to fame, who died before the book was printed".

The authors give us a detailed and enlightening picture of the early days of Vesalius and of the forces which moulded him during his stay in Belgium, France and Italy. Thus in the thirties his early researches had as their driving motive the verification of Galen; but in the forties he had realized that his Paris masters, Guenther and Sylvius, "were almost indifferent to dissection and were enthusiasts only for what Galen had written". Therefore, to achieve his purpose he must put his own hand to the business. Nevertheless, as the authors point out, the break with Galen took longer than he would have us believe, and it is only in the "Fabrica" that he is revealed as a discoverer, and as a "modern man of science with a rovingly enquiring mind and the habit of presenting his own findings in pictorial form". In this connexion an examination of Galenic physiology is called for and given, and we have an admirably clear and informative statement of Galen's views on the movements of the blood, illustrated by a useful diagram.

The failure of Vesalius to admit that his descriptions are often based on animal and not on human anatomy has been revealed by a number of authors, but never so critically as in the present work. It is an almost inexhaustible topic of discussion, and the authors attack it in no carping spirit, but with a sympathetic understanding of the difficulties of the period. They point out that, but for the unfortunate element of deception involved, the animal approach to human anatomy should be counted for righteousness in those who practised it, and that when the Padua professors abandoned the comparative method the greatness of their school faded with it. They admit that Vesalius must certainly have dissected far more animals than men, but add that certain anatomical features are more profitably investigated in animal bodies than in human. Many structural details were examined at first hand by Dr. Singer himself in his critical and fascinating attempt to determine how much of the "Tabulae" and "Fabrica" is to be assigned to animal, and how much to human, anatomy. More remains to be done under this head, and Dr. Singer's results are too striking to remain without companions. The following are the main points so far elucidated: rete mirabile; position and form of the heart; branches of the aortic arch; the caval systems; posterior intercostal vessels; relative levels of kidneys and renal vessels; lobes of the liver; genital organs of both sexes; prostate gland; asymmetry of spermatic veins; segments of sternum.

The introductory matter concludes with a scholarly essay of twenty-one pages by both authors on the anatomical vocabulary of the Renaissance and the Semitic elements in the "Tabulae". The modern history of anatomical terminology may be said to have begun in three works by Joseph Hyrtl, published in 1879, 1880 and 1884, of which the second is the most important. All, however, now need revision, and the present essay points to its authors as the source from which this comprehensive revision should come. They have already done much, but as the "Tabulae" do not include the viscera the entire field has yet to be covered before a substantial vocabulary of medieval anatomy can be attempted. In the meantime, the general index of the present work, combined with the text, provides us with an analysis

of medieval Latin medical and anatomical terms, many of which are still employed, of the greatest value and interest.

Probably most students who are not masters of Eastern languages will value particularly Part 8 of the work, which is an English translation of the "Tabulae Sex", accompanied by 343 exhaustive annotations, and photographic reproductions of the six plates and Latin text. Of the "Tabulae" two complete sets of the original issue are all that have survived, but there are three facsimile editions, only one of which, however, is readily procurable. Now all interested can possess this excellent facsimile copy, which for the purposes of research is as good as the original, and for which we must express our thanks to the authors and also to the Wellcome Historical Medical Museum for undertaking the responsibility of production.

The book has been admirably printed and bound, but exception must be taken to the abominable backing of the six plates. The general editor of the series, Dr. E. Ashworth Underwood, informs us that this was the only material at the printer's disposal, and it was therefore either that or nothing.

Drs. Singer and Rabin are to be warmly congratulated on an addition to Vesalian literature which will surely rank as a classic in times to come.

F. J. COLE

PHYSIOLOGICAL EMBRYOLOGY

Einführung in die Physiologische Embryologie
Von Prof. F. E. Lehmann. (Lehrbücher und Monographien aus dem Gebiete der exakten Wissenschaften, 5.) Pp. 414. (Basel: Verlag Birkhäuser, 1945.) 38 Swiss francs.

THE years between the two World Wars saw a very rapid accumulation of experimental data bearing on the mechanism of development in many groups of animals, particularly the echinoderms and the vertebrates. By the end of the 1930's, most experimental embryologists felt the need for a synthesis, and the elaboration of a theoretical structure by which the facts could be held together in an illuminating way. The disturbances of the War necessitated a slackening in the pace of experimental work, and the leaders of most of the major schools of experimental embryology took the opportunity to try their hand at producing the necessary system of thought. Spemann, whose work provided the original inspiration for much of the recent progress, led off with his "Experimentelle Beiträge zu einer Theorie der Entwicklung" in 1936; then from America we were offered Weiss' "Principles of Development" in 1939, and Child's "Patterns and Problems of Development" in 1941; from Britain, Waddington's "Organisers and Genes" in 1940 and Needham's monumental "Biochemistry and Morphogenesis" in 1942; from Belgium, Dalcq's "L'œuf et son Dynamisme Organisateur" in 1941 and Brachet's stimulating "Embryologie Chimique" in 1944. We are still waiting, not too patiently, for a similar thorough treatment from the point of view of the Swedish school of Runnström and Hörstadius.

It is in the setting of this series of works that Lehmann's "Einführung in der Physiologische Embryologie" will be studied. Prof. Lehmann is known as one of the earlier of Spemann's pupils, and for the last twenty years a steady stream of interesting and very thorough papers have issued from his laboratory in Switzerland, mostly devoted to the analysis of organiser action in the Amphibia. Two thirds of his book are devoted to this group of animals. In the remaining third he discusses the recent work, mainly Swedish, on the echinoderms. This restriction of his field enables Prof. Lehmann to describe the experimental data in considerably greater detail than was possible in most of the books mentioned above, and his work thus provides a summary of facts which will be very useful to the student.

In other respects the results of this policy of exclusion are not so happy. Although the two groups chosen by Lehmann are undoubtedly those in which our knowledge is fullest, yet there are many suggestions of considerable importance to be derived from studies on other animals. Moreover, the epigenetic system of the echinoderm egg is so different from that of the amphibian that a mere discussion first of one and then of the other produces rather two separate monographs than one unified book. The two systems can scarcely be brought into fruitful relation without some account of the spiral-cleaving invertebrates and the Prochordates; while the most direct illumination of the difficult problems in amphibian embryology must be derived from the birds and fish rather than from a group so far removed as the sea-urchins.

Our understanding of the epigenetic processes by which the organism is formed is still at a fairly early stage. The end-results are living animals, organs and tissues. These cannot yet be fully comprehended in physical or chemical terms; and it is thus impossible that a purely physico-chemical theory of development could be adequate. Nevertheless, the theoreticians of experimental embryology are presented with a choice—they may choose to emphasize the more specifically 'biological' aspects of their subject-matter, or they may decide to try to formulate concepts which, as it were, lead towards the realm of physico-chemical ideas. Much of the recent work has been inspired by the second tendency. Although Prof. Lehmann faithfully summarizes this, and indeed speaks highly of its value, his most characteristic ideas seem to belong rather to the former trend. This impression may be partly due to the arrangement of his matter, which he divides into the purely descriptive, the 'entwicklungsmechanisches', and the physiological, a scheme which means that the treatment of each question, instead of proceeding steadily from the biological towards the physico-chemical, is broken into separate parts located in different chapters. This dislocation tends to diminish the field to which the more physico-chemical ideas are applied. Similarly, Lehmann relies to some extent, as any author dealing with this material must do, on such essentially unclear notions as 'fields', gradients, and so on. But he sets this aspect of his theories in the centre of the stage, and goes out of his way to emphasize its organismic character by the frequent use of long German phrases full of overtones —"plastisches Blastemfeld" instead of plain 'field', "Organisatorblastem" for organiser, and such expressions as "topogenetischen begrenzte Selbstorganisation", "kombinative Einheitsleistung", and so on. This type of approach is one which does not appeal to the reviewer as much as does that of some of the other recent works; but it represents a necessary corrective to any possible over-confidence in the complete adequacy of biochemical embryology in its present state.

C. H. WADDINGTON

THE MAGNETIC FIELD OF MASSIVE ROTATING BODIES*

By PROF. P. M. S. BLACKETT, F.R.S.
The University, Manchester

Summary

IT has been known for a long time, particularly from the work of Schuster, Sutherland and H. A. Wilson, though lately little regarded, that the magnetic moment P and the angular momentum U of the earth and sun are nearly proportional, and that the constant of proportionality is nearly the square root of the gravitational constant G divided by the velocity of light c. We can write, in fact,

$$P = \beta \frac{G^{1/2}}{c} U,$$

where β is a constant of the order of unity.

For the first time, the magnetic field of a star, 78 Virginis, has recently been measured (Babcock, 1947). Using the best estimate available for its mass, radius and rotational velocity, the calculated value of the magnetic field agrees with its observed value. We have, therefore, a rough verification of the equation above for three bodies, the earth, sun and 78 Virginis, and covering a range of P and U of more than $10^{10}:1$, though only of 2,000 : 1 in measured field. It is therefore considered that the above equation must be taken seriously as a possible general law of Nature for all massive rotating bodies.

If white dwarfs are collapsed forms of stars like the sun, then they should have the same angular momentum and so, according to the equation above, the same magnetic moment. Owing to their small size, they will have a surface magnetic field of the order of 10^6 gauss. It is suggested that magnetic fields of this order may be in part the cause of the large breadth of the Balmer lines in many white dwarfs, and of the complete absence of any lines in some very dense ones. The various alternative theories of the magnetic field of the earth and sun are discussed. It is suggested tentatively that the balance of evidence is that the above equation represents some new and fundamental property of rotating matter. Perhaps this relation will provide the long-sought connexion between electromagnetic and gravitational phenomena.

1. The Magnetic Field of the Earth, the Sun and a Star

While considering the possible influence of the magnetic fields of stars in the galaxy on cosmic ray phenomena, I noticed two results which seemed to me of great physical interest. The magnetic moments P of the earth and the sun are nearly proportional to their angular momenta U, calculated from the expression

$$U = \frac{2}{5} \omega M R^2 \quad . \quad . \quad . \quad (1)$$

for a uniformly dense sphere of mass M, radius R and angular velocity ω. This proportionality can be seen from the figures in Table 1.

TABLE 1

Body	Mass M (gm.)	Radius R (cm.)	Angular velocity ω (sec.$^{-1}$)	U	H_P (gauss)	P	P/U
Earth	$6{\cdot}0\times10^{27}$	$6{\cdot}37\times10^{8}$	$7{\cdot}3\times10^{-5}$	$7{\cdot}1\times10^{40}$	0·61	$7{\cdot}9\times10^{33}$	$1{\cdot}11\times10^{-14}$
Sun	$2{\cdot}0\times10^{33}$	$6{\cdot}97\times10^{10}$	$2{\cdot}9\times10^{-6}$	$1{\cdot}12\times10^{49}$	53	$8{\cdot}9\times10^{38}$	$0{\cdot}79\times10^{-11}$

Measured values of the polar magnetic fields are also given. These are related to the magnetic moments by the expression

$$H_P = 2P/R^3. \quad . \quad . \quad . \quad . \quad (2)$$

It has long been known that the directions of rotation and of the magnetic moments of the two bodies are similarly related; in fact, in both bodies, the south magnetic poles are near the north geographical poles.

It was natural to compare the mean ratio $(P/U)_1$ of the magnetic moment to angular momentum of these two astronomical bodies with the similar ratio

$$(P/U)_2 = e/2mc = 0{\cdot}88 \times 10^{7} \text{ cm.}^{1/2} \text{ gm.}^{-1/2} \quad (3)$$

for a Bohr magneton. We have

$$(P/U)_1/(P/U)_2 = 1{\cdot}08 \times 10^{-32}, \quad . \quad . \quad (4)$$

and one recognizes immediately that this numerical value is close to that of the well-known non-dimensional ratio

$$G^{1/2}\, m/e = 4{\cdot}90 \times 10^{-22} \quad . \quad . \quad (5)$$

of the gravitational mass of an electron to its charge in E.S.U. We can thus write

$$(P/U)_1 = \beta \frac{G^{1/2}\, m}{e} (P/U)_2, \quad . \quad . \quad (6)$$

where β is a small numerical constant of magnitude about 1/4; whence with (3) we find for the relation between the magnetic moment and angular momentum of both astronomical bodies

$$P = \beta \frac{G^{1/2}}{2c} U. \quad . \quad . \quad . \quad (7)$$

The simplicity of this result, either in the form (6) or (7), suggested that it must have some profound physical significance.

Stimulated thus to study the voluminous literature concerning the origin of the magnetic fields of the earth and sun, I found to my surprise that the essence of these facts had been known for many years, but had, for various reasons, dropped lately out of notice. A survey of this earlier work will be given in the next section.

Seeking a further test of equation (7), I thought at once of the possibility that the magnetic field of some rapidly rotating star might be measurable. I am indebted to Prof. S. Chandrasekhar for giving me early news of the first measurement of the magnetic field of a star that has ever been made. The measurements by Babcock[1] on 78 Virginis have now been published and give a polar field of 1,500 gauss. To calculate P and U we require its mass, radius and angular velocity. From statistical evidence on stars of similar type, the probable values of these quantities in terms of the values for the sun are found to be $M = 2{\cdot}3$, $R = 2{\cdot}0$, $\omega = 25$ (see Section 4). Table 2 gives the resulting data for the star.

TABLE 2

Body	M	R	ω	U	H	P	P/U
78 Virginis	$4{\cdot}6\times10^{33}$	$1{\cdot}4\times10^{11}$	$7{\cdot}3\times10^{-6}$	$2{\cdot}6\times10^{51}$	1500	$2{\cdot}1\times10^{36}$	$0{\cdot}81\times10^{-15}$

We find again about the same ratio for P/U, showing that (7) holds not only for the earth and sun but also for 78 Virginis. The relation between the directions of the rotation and the magnetic field is not known. This further support for the validity of (7) suggests, on one hand, that it must be taken seriously as a possible new general law of Nature, and on the other, that a more rigorous test of its validity must be made, taking into account the variation of density and possibly also of rotation inside the bodies.

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2. Previous Theories of the Magnetic Field of the Earth and Sun

Though the main dipole field of the earth is known to be of internal origin, how it is produced is still obscure. A critical discussion of the extensive literature is given by Chapman and Bartels[2] (1940). The earlier surveys by Schuster[3] (1912), Brunt[4] (1913) and Swann[5] (1923) are still of great value. Possible theories of the sun's field are discussed in a recent paper by Cowling[6] (1945).

Theories of the main field of the earth or sun may conveniently be divided into two classes, which may be called *specific* and *general* theories.

A *specific* theory is one which attributes the magnetic properties of a rotating body to the specific properties of the matter of which it is composed; in such a theory the magnetic moment of a massive body would depend on the specific electrical, magnetic, thermal and mechanical properties of its material, and so is likely to have quite different values for bodies in different physical conditions.

The first theory of this kind, that the earth is ferromagnetic, has long been abandoned, since the internal temperature of the earth is almost certainly well above the Curie points of any materials likely to be present. The obvious alternative is to assume the existence of an electrical conduction current in the earth. The difficulty is to find a mechanism which will maintain it. To explain the sign of the field, a positive current must flow from east to west or a negative one from west to east.

A recent attempt by Elsasser[7] (1939) attributes the current to thermo-electric E.M.F.'s arising from temperature differences in the fluid core due to convective motions. The essential asymmetry required to produce a net circulation around the axis is attributed to the action of Coriolis forces on the convecting masses. In a subsequent paper Elsasser[8] (1941) discusses the relation between the main large dipole field of the earth and the irregular part which amounts to a few per cent of the main field. The origin of both is held to be in the central core of molten metal of radius about $0{\cdot}55\ R$.

A rather similar theory by Frenkel[9] (1945) introduces in addition a self-excitation mechanism, such as had been considered by Gurevich and Lebedinsky[10] (1945) to be the origin of the magnetic field of sunspots. The first theory involving a self-excitation or dynamo mechanism was put forward by Larmor[11] (1919) and was elaborated in detail by Cowling[12] (1933) and shown to fail to explain either the magnetic field of sunspots or the main fields of the earth and sun. Cowling[6] (1945) showed, too, that thermal effects due to convection in the rotating sun give the right sign but in magnitude only 10^{-7} of the observed field. He also shows that the time of electromagnetic decay of the sun's general magnetic field is 10^{10} years, so that the field might be a relic from a different primeval state. But Lamb (for example, see Chapman and Bartel, ref. 2, vol. 2, p. 704) had shown long ago that the decay of currents in the earth would be far too quick to allow the field to be explained as a survival.

A general theory is one that attributes the dipole field to some general property of rotating matter. Already in 1891, Schuster[13], suspecting from the appearance of the solar corona that the sun might have a magnetic field, had put the question, "Is every large rotating mass a magnet?"

The only obvious atomic effect of a general character is that of magnetization by rotation, that is, the gyro-magnetic effect. This gives the right sign, but a moment 10^{10} too small (ref. 2, p. 705). But, as Schuster showed[3], any such uniform magnetization gives a total moment proportional to the volume of the sphere and so a surface field which is independent of the radius. Thus any such theory can be excluded.

In a series of papers, Sutherland[14] (1900–8) assumed that the earth's magnetic field is due to its possession of a positive volume charge compensated by a negative surface charge. He calculated the charge density required and showed that it implies electric fields inside the earth of the order of 10^8 volts per cm. He also noticed that the separation of charges, as calculated from the observed magnetic field of the earth, had about the same magnitude as would occur if gravitation were explained, on the basis of Lorentz's pre-relativity theory (for example, ref. 3), as due to a slight difference between the electric forces between two protons, two electrons, and an electron and a proton. This is, in essence, an early recognition of the numerical result explicitly stated later by Wilson[15] (1923), which expresses in a rather different way the result already given in section 1.

In 1912, Schuster gave a survey[3] of the possible theories and their difficulties, and studied in some detail one similar to that of Sutherland, depending on the assumption of unequal forces between like and unlike atomic particles. Brunt[4] (1913) surveyed many different theories and also showed that the separation of positive and negative charges in the sun's gravitational field could not produce more than 10^{-15} of the sun's magnetic field.

H. A. Wilson[15] (1923), following a suggestion of Schuster[3], showed that one obtained the right order of magnitude for the fields of the earth and sun if one assumed that a moving mass element M, measured in gravitational units, has the same magnetic effect as a moving negative charge Q measured in E.S.U. The measure M of the mass of a body in gravitational units is defined by the equation $F = M_1M_2/r^2$ for the gravitational force between two masses. Comparing this with the expression $F = Gm_1m_2/r^2$, where m_1 and m_2 are measured in grams, we have $M = G^{1/2}m$, whence the gravitational unit of matter amounts to $G^{-1/2} = 3{,}870$ gm.

Wilson's hypothesis, expressed formally, amounted to the assumption that a mass element m gm., or M gravitational units, when moving with velocity v gives, at a distance r, a magnetic field,

$$H = -\frac{M}{cr^3}[v.r] = -\frac{G^{1/2}m}{cr^3}[v.r] \quad . \quad . \quad (8)$$

in analogy to the non-relativistic expression for the magnetic field of a moving charge Q E.S.U., which is:

$$H = \frac{Q}{cr^3}[v.r]. \quad . \quad . \quad . \quad (9)$$

From (8), we find by integration that the magnetic moment P of a sphere of mass M and uniform density ρ, radius R and angular velocity ω, is given by

$$P = \frac{1}{5}\frac{G^{1/2}}{c}\omega MR^2. \quad . \quad . \quad (10)$$

We note that (1) and (10) together give (7), apart from the constant β. The surface magnetic field at the pole is, from (2),

$$H_P = \frac{2}{5}\frac{G^{1/2}}{c}\frac{\omega M}{R}, \quad . \quad . \quad . \quad (11)$$

or expressed in terms of the density ρ

$$H_P = \frac{8}{15}\pi \frac{G^{1/2}}{c}\omega\rho R^5. \quad . \quad . \quad . \quad (11a)$$

Wilson showed that (11) gave the right ratio for the field of the sun and the earth, but numerical values about three times too great.

An alternative way of expressing this result is that the earth's magnetic field is such that would be produced if it possessed a volume negative charge density σ, given in terms of the mass density ρ by

$$\sigma \cong G^{1/2}\rho. \quad . \quad . \quad . \quad (12)$$

Angenheister[14] (1925) also stressed the fact that the assumption of an electric charge density proportional to the mass density gives nearly the correct ratio for the magnetic field of sun and earth. He clearly recognized the physical difficulties of assuming the existence of *real* charges of such a magnitude, and of the large electric fields which must accompany them, in an electrically conducting material such as the earth's core.

Wilson[15] (1923) made a laboratory experiment with a swinging iron bar to test his hypothesis that a moving mass produces a magnetic field. He showed experimentally that the field given by (8), assuming that m is taken as the mass of the earth and v the relative velocity of the iron bar, did not exist. Other arguments against the hypothesis are given in Section 5.

It was probably this disproof of the existence of the field given by (8) which led to the later lack of interest in the approximate validity for the sun and earth of the result expressed by (7). This difficulty about translational, as opposed to rotary, motion had already been discussed by Schuster in 1912, and will be taken up again in Section 5.

Schlomka[17] (1933) has treated in some detail a theory based essentially on Schuster's hypothesis of unequal long-range Coulomb forces between like and unlike particles.

Haalck[18] (1937–38) attributes the required charge separation not to a difference in the Coulomb forces between electrons and nuclei, but to the short-range forces between electrons and molecules, that is, to the forces responsible for the elastic properties of materials. He assumes that such forces would lead to a charge separation proportional to some power of the radius, with a maximum at the earth's centre.

Swann[19] (1927) worked out an elaborate theory based on a small arbitrary modification of the electro-dynamical equations, chosen so as to give the required magnetic field without the unwanted electric field. However, Swann's fundamental hypothesis was that the magnetic field of a rotating body was proportional to $\rho\omega^4R^4$ rather than to $\rho\omega R^2$ as given by (11*a*). This was adopted to avoid the difficulty of translational motion by assuming that the magnetic field due to a mass element depended on certain time derivatives of its velocity, and so is zero for uniform translational motion. Swann chose this particular form since it does give correctly the ratio of the field of the sun and the earth. But it also predicts relatively large fields for rotating bodies on a laboratory scale, and these were later shown by Swann and Longacre[20] (1928) not to exist, thus refuting the theory at least for small bodies. Other objections to Swann's theory are that it is unlikely that the vector quantity P will depend on an even power of the vector ω, and that the theory in no way gives the correct numerical value of the magnetic moment except by the introduction of arbitrary parameters.

The Case for a General Theory.

Chapman and Bartels[2] (1940, vol. 2, p. 707) discuss these various theories in some detail but do not give much prominence to the particular parts of the work of Sutherland, Schuster, Wilson and Angenheister, which together establish the results already given. They sum up on the whole against a theory of the type here called a *general* theory and in favour of a *specific* theory of some type; but they do not find that any then existing specific theory is tenable. Their main reasons for the rejection of a general theory lay in the facts of the obliquity of the magnetic and rotational axes, which is 4° for the sun and 12° for the earth, and the existence of the secular variation. For the earth this means that a field amounting to some 10 per cent of the main symmetrical field would remain to be explained even if a general theory served to explain the main field. It seems to me, however, that, given a general explanation of the main field, then the convective motions, etc., that must exist in the earth's interior may well be found to modify the main field sufficiently to produce the observed field.

It is surely far more difficult to find a specific theory that will give the two striking results: (*a*) that the magnetic moments of the sun and the earth are nearly proportional to their angular momenta—the range of variation of both being more than 10^8 to 1; and (*b*) that the constant of proportionality is nearly $G^{1/2}/c$, than it is to explain a deviation in the directions of the two axes and the existence of the secular variation.

It seems extremely unlikely that the approximate validity of equation (7) could be accidental. Its simplicity, involving as it does only the two macroscopic constants G and c, is in striking contrast to the complexity and arbitrary character of all special theories hitherto put forward, and their failure so far to provide a quantitative explanation either of the field of the earth or of the sun, far less of both.

The occurrence only of the constant $G^{1/2}/c$ multiplying the angular momentum U seems to exclude, except by way of a remarkable number of numerical accidents, the possibility that any specific properties of the rotating body, other than its size, mass and rotation, can determine its magnetic field.

If P does depend only on the macroscopic quantities M, R, ω, G, c, then dimensional considerations can be used to find the possible functional forms. Restricting our consideration to cases where P is proportional to M, we find that P can be put in the form

$$P \propto G^{1/2}c^{-1}\omega MR^2 f(\omega R/c). \quad . \quad . \quad (13)$$

For $f(\omega R/c) =$ constant, this gives our original expression (7). Since P must vary as an odd power of ω, the next likely expression is given by taking $f(\omega R/c) = (\omega R/c)^3$, giving

$$P \propto G^{1/2}c^{-3}\omega^3 MR^4. \quad . \quad . \quad . \quad (14)$$

Now our original expression gives both the observed variation of P with M, ω and R and the rough correct numerical magnitude, while the second gives neither one nor the other. It will be noticed that the second expression differs from the first by the factor $(\omega R/c) = v/c$, when v is the peripheral velocity. It is, of course, probable that at very high peripheral speeds a relativity correction involving $(v/c)^2$ would have to be introduced.

3. The Angular Momentum of a Star

As has already been explained, the approximate validity of (7) was first noted by comparing the magnetic moments of the earth and sun, assuming both to have uniform density. This, however, is far from being the case, especially for the sun, so it is necessary to take into account the central condensation of these bodies when calculating their angular momentum U.

It is convenient to introduce the ratio

$$k = I/I_0 \qquad . \quad . \quad . \quad . \quad . \quad (15)$$

of the moment of inertia of a given centrally condensed sphere to that of a sphere of the same radius, angular velocity, and with a uniform density equal to the mean density of the centrally condensed sphere. Then, instead of (1), we have

$$U = \frac{2}{5}k\omega MR^2. \qquad . \quad . \quad . \quad (16)$$

For the earth and major planets k is known from the work of Jeffries[21] (1924, 1937). For the sun and other stars, its value must be calculated assuming some given stellar model. First, we have the Emden polytropic gas spheres for which Eddington[22] (1926) quotes the density distributions for three values of the index n. Then there is the more recent point convective model of Cowling[23] (1935) for which new numerical calculations have been made by Blanch, Lowan, Marshak and Bethe[24] (1941) and Marshak and Blanch[25] (1946).

From their density distributions the values of k have been calculated roughly by graphical integration, leading to the figures given in Table 3, together with the ratio of the central density ρ_0 to the mean density $\bar{\rho}$.

TABLE 3. CENTRAL DENSITY ρ_0 AND RELATIVE MOMENT OF INERTIA k OF STELLAR BODIES

	$\rho_0/\bar{\rho}$	$k = I/I_0$
Uniform sphere	1·00	1·00
Polytrope $n = 2$	11·4	0·40
,, $n = 2·5$	24·1	0·28
,, $n = 3$	54·3	0·20
Point convective model	79·3	0·14
Earth	3·3	0·88
Jupiter	?	0·66

There is thus considerable uncertainty in the value of k for the sun. In what follows, we will assume the value 0·16 as the mean for the point convective model, and the polytrope with $n = 3$.

Non-uniform Rotation.

From considerations of stability it appears probable that the angular rotation of a gaseous stellar body cannot be uniform, but it is likely to increase inwards (see discussion by Milne[26], 1930, p. 241). On the other hand, it is known that the surface rotation of the sun is about 40 per cent slower at the poles than at the equator. Though so far there appears to be no certain way of estimating the magnitude of this effect, it is convenient to introduce a quantity defined by

$$\eta = U/U_0,$$

where U is the true angular momentum, and U_0 is the angular momentum calculated from the observed peripheral equatorial velocity, taking into account the variation of density but not the variation of the angular velocity. Then we know that η is of the order of, but probably rather greater than, unity.

I am indebted to Prof. Cowling for informing me that the mean period of rotation of the whole mass of the sun is very uncertain, but is probably not shorter than ten days, though it may be actually more than twenty-five days. This gives a limit of η between 2·5 and, say, 0·7.

We have therefore the following expression for the angular momentum of a rotating celestial body:

$$U = \frac{2}{5}k\eta\omega MR^2, \qquad . \quad . \quad . \quad (17)$$

and so, with (2) and (7)

$$H_P = \frac{2}{5}\beta G^{1/2}k\eta\omega M/Rc, \qquad . \quad . \quad . \quad (18)$$

where ω is the observed angular velocity of the surface at the equator. For a few stars the values of M and R are known accurately, but in general they have to be deduced statistically. The values of k and η can, of course, only be derived from some theoretical model of the interior of the star.

4. The Magnetic Field of a Rotating Star

4.1. *Babcock's Measurements on 78 Virginis*

It has long been known that many stars are rotating much faster than the sun, and so, on our hypothesis that equation (7) has general validity, should have large magnetic fields. But it is only quite recently that the magnetic field of any star except the sun has been measured. This has been achieved by H. W. Babcock[1] (1947) for 78 Virginis (spectral type $A2$), and, as has been explained in Section 1, it is satisfactory to find that within the rather large error of the measurement of the magnetic field and the statistical uncertainty of the estimation of the mass, radius and angular velocity, the results are in agreement with expectation, though the relation between the directions of the magnetic field and rotation is not known.

The rotational velocity of stars is measured by the broadening of spectral lines due to the Doppler effect of the light from different portions of the disk. A general account of the method is given by Elvey[27] (1930), Rosseland[28] (1936, p. 202) and Becker[29] (1942, p. 66). Stars of early spectral types O, B and A and early F are usually found to be in rapid rotation, with a most frequent peripheral velocity of about 100 km./sec., compared with the 2 km./sec. peripheral velocity of the sun (type $G0$). A small fraction have velocities of more than 200 km./sec. (see Table 4). The rotations seem to disappear rather suddenly between $F2$ and $F5$ types, and no observable rotations, that is, with peripheral velocities more than, say, 20 km./sec., have been observed for later spectral types. A few stars of the early types have, however, fine spectral lines, and this is interpreted as indicating that their rotational axes are parallel to the line of sight. It is only on such stars that the Zeeman effect can at present be measured.

Babcock's measurements on 78 Virginis give a polar field of 1,500 gauss. He assumes a peripheral velocity of 60 km./sec., and compares these figures with the field of 53 gauss and velocity of 2 km./sec. for the sun, concluding that the field is proportional to the peripheral velocity. This, however, lacks physical plausibility.

To test equation (7) we need M, R and ω. From tables given by Becker[29] (1942, p. 64) for the different spectral classes, we find for a star of type $A2$ that $M = 2·3$ and $R = 2·0$ in terms of values for the sun. From data on rotation given by Becker (p. 69) and reproduced in Table 4, the median peripheral velocity for A type stars appears to be about 100 km./sec. rather than the value of 60 km./sec. assumed by Babcock. The angular velocity ω must therefore be twenty-five times that of the sun, that is, nearly the same as for the earth.

TABLE 4. DISTRIBUTION OF ROTATIONAL PERIPHERAL VELOCITIES FOR STARS OF EARLY SPECTRAL TYPES, BECKER[32] (1942)

Velocity (km./sec.)	Type O, B (%)	Type A (%)	Velocity (km./sec.)	Type O, B (%)	Type A (%)
25	—	13	150	15	12
50	27	17	175	—	8
75	—	11	200	4	7
100	53	10	225	—	4
125	—	14	250	1	1

Assuming that k and η have the same values for the sun and 78 Virginis, the ratio of their polar fields, according to (11), should be proportional to $\omega M/R$, and so should have the value 29, whereas the observed value is 28. Considering the statistical nature of the data for the star shown clearly in Table 4, the closeness of the above agreement must be considered quite accidental. The direction of the magnetic field was determined, but not, of course, the direction of rotation. So no comparison of the signs of P and U is possible for this star.

4.2. *Collected Data for the Earth, Sun and 78 Virginis.*

In Table 5, we have given collected data for the three bodies. For the earth, the component along the axis of rotation of the dipole moment as given by Chapman[30] (1943) is used.

TABLE 5. RATIO P/U ALLOWING FOR CENTRAL CONDENSATION

	Magnetic moment $P=\frac{1}{2}HR^3$	k	Angular momentum $U=\frac{2}{5}k\omega MR^2$	$\frac{P}{U}$	$\beta=\frac{P}{U}\div\frac{G^{1/2}}{2c}$
Earth	$7{\cdot}9\times10^{25}$	0·88	$6{\cdot}22\times10^{40}$	$1{\cdot}30\times10^{-15}$	0·30
Sun	$8{\cdot}9\times10^{32}$	0·16	$1{\cdot}80\times10^{41}$	$4{\cdot}9\times10^{-15}$	1·14
78 Vir.	$2{\cdot}1\times10^{33}$	0·16	$4{\cdot}2\times10^{41}$	$5{\cdot}0\times10^{-15}$	1·16

Quite recently, one uncertainty, that of the nature and magnitude of the sun's dipole field, has been cleared up. Hale's early measurements showed a much more rapid decrease of H with height in the sun's atmosphere than would correspond to the field of a dipole. However, the work of Thiessen[31] (1946) seems finally to have established the existence of a dipole field for the sun, and gives a value for the polar field of 53 ± 12 gauss.

In the last column of Table 5 are given the values of β, calculated from (7) by inserting the observed values of P and U and taking $G^{1/2}/2c = 4{\cdot}31 \times 10^{-15}$ cm.$^{1/2}$ gm.$^{-1/2}$. It will be noticed that β is nearly unity for the sun and 78 Virginis, but about 0·3 for the earth; the latter fact had been originally noticed by Wilson[15] (1923). Alternatively, β can be obtained directly from the expression

$$\beta = \frac{5}{2} H_P Rc/k\omega MG^{1/2}. \quad . \quad . \quad . \quad (18a)$$

This equation is convenient as showing the effect on β of errors in the various quantities.

It is noteworthy that the close proportionality between P and U for the earth and sun, found on the assumption of uniform densities (Section 1), is destroyed by taking into account the central condensation of the sun and the stars.

In Table 6 the observed relative values of H_P for the three bodies are compared with the values calculated from (7), assuming that the angular momenta are calculated from equation (1) for uniform density, and equation (16) for centrally condensed spheres.

TABLE 6. OBSERVED AND CALCULATED POLAR FIELD

	H_P (observed)		Uniform density $\frac{M\omega}{K}$	Central condensation k	$\frac{3M\omega R}{K}$ (rel.)
	gauss	relative			
Earth	0·61	1·0	1·0	1·0	1·0
Sun	53±12	86	121	0·16	20
78 Vir.	1500	2450	3500	0·16	550

4.3. *Possibility of Further Tests on Stars of the Main Sequence.*

Clearly, further measurements of the magnitude and direction of the magnetic field of highly rotating stars are of great importance to test the theory. Babcock[1] (1947) has stated that it might be possible to find the relation between the directions of H and ω on a visual binary. As shown in Table 4, some stars of the early spectral classes, rather similar to 78 Virginis, have rotational velocities about 2·5 times as high (see also Struve[33], 1930, Westgate[33], 1933, 1934). Such stars should therefore have a polar field of about 4,000 gauss.

The maximum magnetic field is set by the Roche Limit giving the maximum angular velocity ω_m for stability. This is given by

$$\omega_m = 1{\cdot}52\, G^{1/2}\, \bar{\rho}^{1/2}, \quad . \quad . \quad . \quad . \quad . \quad (19)$$

where $\bar{\rho}$ is the mean density (Jeans[34], 1928, p. 246). This suggests that angular rotations up to some four times that of 78 Virginis are possible, thus giving a maximum field for this type of star of about 6,000 gauss. If we insert ω_m from (19) in (11a), we see that the maximum possible field H_m of a star is proportional to $\bar{\rho}^{3/2} R^2$. From the variation of $\bar{\rho}$ and R with spectral type (ref. 1, p. 62), we see that H_m varies rather slowly with spectral type along the main series. Relative to the value for the sun ($G0$), we find $H_m = 1{\cdot}2$ for ($M0$) and 0·5 for ($B0$) type. These later types, though apparently not normally rotating fast, are capable dynamically of giving greater fields than early types.

The most satisfactory test would, of course, be on a star for which the magnitude and direction of both the magnetic field and angular velocity could be measured directly, rather than having to rely on a statistical argument for the determination of the rotation, as for 78 Virginis. It seems that this might, in principle, be done by measuring both the Zeeman effect and the Doppler effect of the light from the nearly eclipsed edge of the rear component of an eclipsing binary. But probably the experimental difficulties would be very great.

4.4. *The White Dwarfs.*

The white dwarfs should also have a large field if they are rotating with comparable angular velocities to the sun, owing to the high values of the ratio M/R on which the field depends (equation 11). The values for several white dwarfs of this ratio, which is also the ratio governing the red shift, are between twenty and thirty times that of the sun (Russell[21], 1945, p. 760), and so should give a field of about 1,300 gauss. If, however, for example, the dark companion of Sirius has the same angular velocity of rotation as Sirius itself, that is, eight days, its magnetic field would be about 5,000 gauss.

It has been suggested by Kuiper[16] (1941) that possibly white dwarfs have angular *momenta* comparable with that of the sun, as would be expected if they are formed by the collapse of such stars. Now Sirius B has nearly the same mass as the sun but only a fiftieth of its radius. If its angular momentum is equal to that of the sun, so will be, according to our hypothesis, its magnetic moment. Consequently its magnetic field will be 50^3 times as great; that is, its equatorial field will be 3×10^6 gauss.

Now the most prominent lines in the spectra of white dwarfs, and often the only lines, are the

hydrogen Balmer series. These lines are, however, much broader than for normal main sequence stars. This greater breadth is generally ascribed to pressure broadening, that is, to the Stark effect due to atomic collisions, which should be exceptionally great in these stars owing to the high pressure associated with the very intense gravitational fields. It appears from the discussion by Kuiper[36] (1941) that a rough quantitative explanation on these lines is possible.

It is, however, interesting to note that a magnetic field of a few million gauss will also produce a broadening of the observed magnitude. For the double Zeeman separation of a normal triplet of the wave-length of $H\gamma$ is nearly 2×10^{-5} A./gauss, so the breadth of the Zeeman pattern should be about 60A. It must be remembered that owing to the Paschen–Back effect the Balmer lines will give nearly the normal triplet. Since the polar field is twice the equatorial field, this calculated breadth will approximately represent the double width to half intensity of the light from the star as a whole. Sirius *B* itself seems to have rather finer Balmer lines than 60A., and also some metallic lines. However, a number of white dwarfs, for example, 40 Eridani *B* and Wulf 1346 have Balmer lines of widths of about 50A. (Kuiper[36], 1941). Thus it cannot be considered unplausible to suppose that the line widths of white dwarfs are markedly greater than main sequence stars, not only because of a large Stark effect but also in part because of a large Zeeman effect. The comparison given by Kuiper of the spectra of 40 Eridani *B* with a comparison star shows that the line width of the latter, probably to be attributed to pressure broadening, would be enough to obscure the typical double-triplet structure of a Zeeman pattern in the white dwarf.

Many of these stars show a rather fine central core to the broad Balmer lines which is difficult to explain as due to Stark effect; and it is possible that this is caused by the undisplaced components of the Zeeman pattern, which will be the same all over the disk.

It is perhaps significant that most of the white dwarfs which are believed to be still smaller than Sirius *B* show no Balmer lines at all (Wulf, 489, 457, 219) or very shallow ones (AC. 70, 8247). One star, Ross 627, is anomalous in this respect, as it has rather fine lines but is nevertheless believed to be very dense.

In the spectrum of (AC. 70, 8247) there are two shallow lines more than 100 A. in breadth and centred on 4480 A. and 4140 A. If these are identified with $H\gamma$ (4341) and $H\delta$ (4102) and their breadth attributed to Zeeman effect, the required magnetic field is about 10^7 gauss. Taking Kuiper's estimate (ref. 36, p. 234) of the radius as 0·004 of that of the sun, the magnetic moment and so the angular momentum of the star relative to the sun will be $(10^7/25) \times (0{\cdot}004)^3 = 0{\cdot}024$. It is, however, possible that the observed shallow lines do not represent the whole absorption line but only the finer central core. In this case the real breadth will be considerably larger than 100 A., and so the angular momentum also will be larger—thus bringing it nearer to that of the sun.

Clearly, polarization measurements on the spectra of the white dwarfs are urgently needed, and calculations of the line profiles which would result from the combination of the Zeeman effect in large fields with pressure broadening.

I am indebted to Prof. H. H. Plaskett for pointing out that there is one white dwarf, Wolf 489 (see ref. 36, p. 211), which lends support to the explanation of the broadening by Zeeman rather than Stark effect. This star is unusual in being of a later colour type (*G*8) and so should show strong lines of ionized calcium. In fact, it shows no lines at all. Since Ca^+ lines are very much less influenced by the Stark effect than hydrogen lines, it is difficult to explain their absence as due to the Stark effect. Thus the Zeeman effect, to which the H and Ca^+ lines are equally sensitive, provides a more plausible explanation.

Since the Zeeman breadth $\Delta\lambda_Z$ is proportional to the surface magnetic field and so, according to (2) and (7), to U/R^2, while the Doppler breadth $\Delta\lambda_D$ is proportional to the peripheral velocity and so to $U/M.R$, the ratio $\Delta\lambda_Z/\Delta\lambda_D$ is proportional to M/R^2 and so is independent of the rotation. For very small and dense stars the Zeeman breadth becomes greater than the Doppler breadth. For Sirius *B*, $\Delta\lambda_Z$ is about twenty times $\Delta\lambda_D$. The two breadths will be equal for a star of about the sun's mass, which has a radius about five times that of Sirius *B*. The period of rotation of Sirius *B*, if it has the same angular momentum as the sun, is fifteen minutes, and its peripheral velocity 100 km./sec. Owing to the high density, the limiting period set by the Roche limit is about forty seconds.

4.5. *The Major Planets.*

Another interesting possibility is that Jupiter might have a measurable field. Take the value of k as 0·66, as given by Jeffries[21], with $R = 7{\cdot}0 \times 10^9$ cm., $\bar{\rho} = 1{\cdot}35$, $T = 9{\cdot}8$ hours, we find from (18*a*) that the polar field is about 30 gauss, using the value of β for the earth, and 120 gauss with the value for the sun. Probably such a small field would be unmeasurable, as the only spectral lines available are apparently the absorption bands of methane and ammonia; the low temperature 150° abs. would, however, help by making the lines narrow.

5. Theoretical Discussion

5.1. As has already been explained, early attempts to explain the magnetic field of the earth on the lines of a general theory tentatively assumed that the earth was in some way electrically charged. Since the earth has a very small external electric field, it was necessary to assume that the net charge was zero, and so a separation of positive and negative charges within the earth was postulated. To explain the sign of the magnetic field, it was necessary to suppose that the negative distribution was displaced outwards. A special case of such a distribution (Sutherland[14], 1904) is that of a uniform positive volume charge combined with negative surface charge of equal total magnitude.

A charge separation theory of this type has the great merit of explaining very simply the existence of a magnetic field due to a rotating body, and the absence of a magnetic field due to pure translational motion. Provided, however, that the normal laws of electro-magnetism are assumed, it is quite impossible to believe in the existence of a real charge-separation of the required magnitude. This is given by (12), and for the earth is of the order of 10^{-3} E.S.U., or 10^6 electrons per unit volume. But such a charge distribution implies an electric field inside the earth of the order of 10^9 volts/cm., which is greater than the dielectric strength of any known material. In

the sun its non-existence is still more obvious. Since the conductivity both of the central core of the earth and of the ionized matter in the sun are relatively high, any such charges which were produced by any static E.M.F. would very rapidly be conducted away. Chapman[27] (1928) and Cowling[4] (1945) have calculated that the conductivity of the matter at the sun's centre is of the same order as that of copper at normal temperature.

Actually there will, of course, be some separation of positive and negative charges in an ionized gas in a gravitational field, due to the large difference in mass between the electrons and the positive ions. Pannekoek[28] (1922) and Rosseland[29] (1924) have treated this question (see ref. 22, 1926) and have proved from the Maxwell–Boltzmann equation that a charge density of magnitude

$$\sigma_g = G\rho\mu/e, \quad . \quad . \quad . \quad . \quad (20)$$

when μ is the mass of the positive ions and e is the electronic charge, will be produced by the tendency of the electrons to move to regions of higher gravitational potential.

For the sun, the mean molecular weight is about 2·2 in terms of the hydrogen atom. Comparing (20) with (12), we see that the ratio of the charge density and so the electric field, due to this separation of electrons and ions in the gravitation field, to the charge density and electric field necessary to explain the magnetic field of the earth, is about 10^{-17}. Essentially the same result was obtained earlier by Brunt[4] (1913) in a less general form. The sign of the charge distribution is the same as that required to explain the magnetic field, that is, the negative charge is outermost.

Cowling[46] (1929) has pointed out that when an ionized medium in a gravitational field is moving at right angles to a magnetic field, then the electric field due to the separation of the charges is considerably greater than that given by (20). It is still, however, far too small to explain the observed magnetic moments.

If the normal electro-magnetic equations are assumed valid, it is clear that no adequate real charge separation can exist. Thus some alteration in the fundamental equations seems inevitable. Further, it is difficult to believe that any possible alteration of the electro-dynamical equation can allow the existence of a real charge density in the earth and sun of the required magnitude. Still, it is possible that the charge separation theories of Schuster, Schlomka and others, which depend on the hypothesis of lack of exact equality between protons and electrons, etc., may repay further study.

Another type of alteration of the electro-magnetic equation is that proposed by H. A. Wilson, who postulated that a mass in moving with velocity v, even though electrically neutral, produces a magnetic field given by (8).

This hypothesis, however, is certainly untrue, if v is interpreted as a relative translational velocity. For example, an observer in an aircraft moving at 500 km./hr. relative to the earth can be considered as at rest with the earth moving past him at the same velocity. Thus, according to (8), he should observe a magnetic field of the order of 1 gauss and with a direction quite different from the actual field of the earth. Again Wilson disproved this relation by a laboratory experiment.

There is also, of course, a theoretical objection to the existence of any magnetic field associated with the translational motion of a neutral mass. For the normal Lorentz transformations for free space show that the magnetic field given by (8) can only exist if the assumed 'neutral' mass has an electric charge $Q \sim G^{1/2}m$; this contradicts the assumption that the mass is uncharged.

We must conclude, therefore, that a neutral mass with a pure translational velocity does not produce a magnetic field according to (8). However, for the purpose of explaining equation (7), it may not be necessary to assume that (8) is true for pure translational motion. If, for example, the velocity of a mass element δm is interpreted as that velocity relative to an observer which is produced by the absolute rotation of the body, then one can use (8) to explain (7) without necessarily concluding that a neutral mass in pure translational motion produces a magnetic field. We conclude, therefore, that equation (8), with an additional multiplying factor β, may possibly provide a tentative explanation of (7), provided v is defined as the relative velocity due to rotation as measured with reference to the inertial frame of the universe, that is, by the equation $v = [\omega.R]$, when ω is the measured absolute rotation and R the radius vector from the centre of gravity.

It is not, however, clear to me whether it is, in fact, possible to retain (8) for rotational motion and deny it for translational motion without some far-reaching alteration in the electro-magnetic and dynamical equations. No difficulty occurs in the application to a single rigid rotating body, but how to avoid difficulties in connexion with the orbital motion of, say, the planets or a double star is not so clear. As has already been pointed out, this difficulty does not occur on the hypothesis of a real charge separation. For here we have two equations of type (9), one with Q and H positive and one with them negative. It is the cancellation of the magnetic fields from the opposite charges which give a magnetic field for rotational but not for translational motion. The problem is whether one can obtain the same result with the single equation (8). If this proves impossible, then one may be forced back on some theory equivalent to the assumption of virtual electric charges, that is, charges which produce a magnetic field but not an electric field. A hint of how this might be done may possibly be obtained from considering the field of the neutron.

At the time of the first attempt to explain the magnetic field of the earth, no magnetic fields were known except those associated with a movement of electric charges or with a time variation of electric intensity. This is no longer the case, since it is now known that the neutron has a magnetic moment. This amounts to 1·80 Bohr nuclear magnetons, and the magnetic moment and spin vectors (angular momentum) are opposite in direction, as they are for the earth or sun. In some current meson-field theories, the difference between the magnetic moments of the neutron and proton are attributed to the existence of virtual mesons, thus bringing in virtual but not real electric charges. Possibly this might be taken as a hint that the magnetic field of a massive rotating body might be attributed to such a virtual charge separation. The observed linear variation of H with ω shows that such a virtual charge separation cannot be the result of the rotation but must be a property of a massive body at rest.

Since the ratio P/U for a neutron is about 10^{-8} of that for a Bohr atomic magneton, it can be seen from (6) that there is no obvious numerical relationship between P/U for a massive body and P/U for a neutron, unless one quite arbitrarily introduces such a non-dimensional ratio as $e^2/hc = 1{\cdot}16 \times 10^{-2}$.

It seems at present impossible to find an explanation of the fact that $\beta \cong 0{\cdot}3$ for the earth and about unity for the sun and 78 Virginis. The screening effect of ferromagnetic materials in the earth's crust could not possibly give an effect so large as 1 per cent. It is, of course, possible that the fault lies with the values of k and η assumed for the sun and 78 Virginis. If the products $k\eta$ were in reality three times as large as assumed, the discrepancy would be removed. But so also would be the attractive feature that β is nearly unity for the sun and 78 Virginis.

An alternative possibility is that the difference is due to some small effect of the *specific* properties of terrestrial or stellar matter, superimposed on the *general* mechanism responsible for the existence and order of magnitude of the main field. One might, perhaps, attribute the difference of the value of β to, say, the proportion of free electrons in the matter, or to the ratio of protons to neutrons.

Clearly the experimental result (7) and its hypothetical explanation (8) are to be considered as holding only for the non-relativistic case. When peripheral velocities comparable with c occur, modifications are clearly to be expected.

In general, it seems very probable that a satisfactory explanation of equation (7) will not be found except within the structure of a unified field theory. In this connexion equation (6) may be of special significance in view of the important part that the non-dimensional rate $G^{1/2}m/s$ must play in any such theory.

5.2. *The Magnetic Field of an Asymmetric Body.*

We have implicitly assumed so far that the static magnetic field given by (7) for a sphere must ultimately be expressible as an integral over all parts of the body. Though equation (8) represents one differential form which gives the observed result for a sphere, apart from the numerical factor β, we must inquire if there are likely to be solutions of a different type. For the following reasons this seems unlikely. First, the fact that, for a sphere, H is found experimentally to vary as ρ (see equation (11a)), implies that H must be expressible as the vector sum of contributions δH from each mass element considered separately. For if, for example, δH for a mass element depended not only on δm, but, say, also on the gravitational potential at the element, then H for the whole body would not be a linear function of ρ. If, therefore, we assume that each mass element gives an independent contribution to the total field, then (8) appears the only form which will give the observed linear dependence of H on ω.

It is possible, of course, that the correct solution is of the form of (9) rather than (8), where δQ is interpreted as some form of virtual charge taking both positive and negative values. If this is so, then δQ for any volume element may depend on the whole configuration of the body, as it would for a real charge separation, and not only on δm.

Until this question is settled, it is not possible to calculate the magnetic field of an asymmetric body, such as a massive ellipsoid rotating, say, about its shortest axis. This is of importance in connexion with possible laboratory experiments, as it might prove technically easier to measure the alternating field which one would expect from such an asymmetrical body, rather than the static field of a symmetrical one.

The general question then arises as to whether one can, in fact, extrapolate (7) and (8) to the laboratory scale. Though (7) holds experimentally roughly over a range of U of more than $10^{10}:1$ for the three astronomical bodies, does this justify the necessary extrapolation of $10^{28}:1$ from the earth to the case, say, of a bronze sphere of 1 metre diameter rotating at 100 r.p.s., which should give a field of about 10^{-8} gauss (see next section).

The physical conditions of the material of such a laboratory sphere differ so widely from that of the earth, not only in respect of size, but also of temperature, pressure and tension, ratio of gravitational to centrifugal forces, etc., that little can be concluded until a consistent theory of (7) has been found.

It may be noted that the separate ranges of R, ω and ρ for the three astronomical bodies are about $220:1$, $25:1$, and $14:1$, respectively. The extrapolation to a laboratory sphere involves an extrapolation of $1:10^{-7}$ for R, and $1:10^{7}$ for ω.

5.3. *Possibility of Laboratory Test.*

Assuming that the extrapolation is justified, we can calculate the maximum field from a sphere of given material. Giving β the value 0·30 as for the earth, the polar field of a rotating sphere is found from (11a) to be—

$$H_P = 1{\cdot}07 \times 10^{-15}\rho\omega R^2. \quad . \quad . \quad (20)$$

In this expression we have to insert the maximum possible value ωm rad./sec. consistent with the maximum safe tensile stress S gm./cm.^{2}; using for this the value for a disk given by Svedberg (1940), which can be put in the form

$$\omega m = 50\, S^{1/2}\rho^{-1/2}R^{-1}, \quad . \quad . \quad (21)$$

we find

$$H_P = 5{\cdot}4 \times 10^{-14}S^{1/2}\rho^{1/2}R. \quad . \quad . \quad (22)$$

We thus see that $H_P \propto R$, hence the advantage of a large body rotating correspondingly slowly. Taking $\rho = 8$, and, for example, $S = 3{\cdot}0 \times 10^8$ gm./cm.^{2} or 43,000 lb./sq. in., we find:

$$H_P = 2{\cdot}6 \times 10^{-10}R. \quad . \quad . \quad . \quad (23)$$

For a 1-metre sphere ($R = 50$ cm.), the maximum speed is 100 r.p.s. and $H_P = 1{\cdot}3 \times 10^{-8}$ gauss. For a 10-metre sphere, the speed is only 10 per sec. and the field is $1{\cdot}3 \times 10^{-7}$ gauss. If it should turn out that the correct value of β to take is that for the sun rather than that for the earth, these fields would be multiplied by three.

If an asymmetrical body of the same maximum linear dimensions were used, then one would obtain a smaller field than that given by a sphere; but the fact that it would be alternating might permit detection of this smaller field more easily than is possible for the static case.

The only experiment which appears to have been carried out to attempt to detect the magnetic field of a rotating body is that of Swann and Longacre[10] (1928), who spun a copper sphere of 10-cm. radius at 200 r.p.s. According to (20) the field should be

about 10^{-9} gauss. The experimental method was only sensitive enough to show that no field so large as 10^{-4} gauss was produced.

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BRITISH ECLIPSE EXPEDITION TO BRAZIL

IN consequence of the aeroplane disaster at Dakar in the early hours of April 13, the British expedition to observe the total eclipse of the sun of May 20 at Araxa in Brazil has been cancelled.

The programme approved by the Joint Permanent Eclipse Committee of the Royal Society and the Royal Astronomical Society comprised four items.

The profiles of the chromospheric lines were to be observed using a Michelson echelon grating. The apparatus devised provides for a succession of short exposures at several points of the sun's limb to study the variation of profile and intensity with height above the sun as the moon successively masks off the lower layers. Some indication was hoped for of transition from photospheric temperatures to the high excitation temperatures now attributed to the coronal regions.

The corona was to be photographed in its own green monochromatic radiation through a large aperture (13·5-cm.) Fabry–Perot étalon to gain information on internal motions or rotation and to determine the profile of the green line accurately, also with a view to temperature assessment. The plates of the étalon had a separation of just over 1 mm. and were aluminized to give a resolving power of some 400,000. The coronal image would be crossed by arcs of circular fringes the displacement or distortion of which would reveal the motions. These two instruments were designed by Dr. J. A. Carroll, now deputy for research and development to Controller of the Navy and scientific adviser to the Board of Admiralty, during his occupancy of the chair of natural philosophy at Aberdeen.

In addition, it was planned to determine the darkening towards the limb by using one of the infra-red photo-cells, developed at the Admiralty Research Laboratory, with suitable recording gear.

Observations to measure solar radio noise at a frequency of about 60 megacycles/sec. were also planned with the collaboration of the War Office and Ministry of Supply, apparatus having been prepared by Dr. J. S. Hey and Major S. J. Parsons.

Dr. Carroll had been asked to take charge of the expedition, its organisation and preparation by the Joint Permanent Eclipse Committee, assisted by Dr. A. Hunter from the Royal Observatory, Greenwich, and one or two others, depending on what could be organised in the time available. During the period of preparation, he succeeded Mr. A. P. Rowe in the chief scientific post at the Admiralty, and it was impracticable for him to give the time required for preparation of, and participation in, the expedition as originally contemplated. The specialized nature of the equipment made assistance hard to find. Dr. Alan Baxter, who had been on Prof. Carroll's staff in Aberdeen, was familiar with it and had participated substantially in its design and development there for use in Omsk in 1936, but he had become a principal scientific officer in the Royal Naval Scientific Service. The Board of Admiralty took the view that, in the circumstances, it was reasonable that they should advance pure scientific research by making their scientific officers' services available to the expedition. The remaining expert optical member required for the team was Mr. J. H. Strong, of the Spectroscopy and Astrophysics Department of the Imperial College of Science and Technology.

During the last few months of 1946 and the first three of 1947, the equipment was assembled, modified and tested by this team in a room made available at the Admiralty Research Laboratory and with assistance from the Laboratory's workshops. The intention was that the gear and three observers, Dr. Baxter, Dr. Hunter and Mr. Strong, should proceed by sea in time to give them a clear month on the site, they being joined about ten days before the eclipse day by Dr. Carroll and Major Parsons. Various factors, among them the fuel crisis in Britain, caused the last ship which could be relied upon to reach Rio de Janeiro in time to be one due to sail on March 11. This was only known a few days beforehand, and it was barely possible to complete testing, dismantle all instruments, pack them and get them on board, particularly as the fuel cuts and the weather had seriously slowed up the later stages of the work. However, the gear, with the exception of the Fabry–Perot étalon and certain parts of an image rotator used in the echelon spectrograph, was dispatched, and arrangements made for the three observers to go out by air a month later. In attempting landing at Dakar while the airfield there was fog-bound, the aeroplane carrying the observers broke up, Dr. Baxter being killed instantaneously, Mr. Strong receiving injuries which at first were thought not dangerous but later proved fatal (see p. 667). Dr. Hunter escaped with severe cuts and abrasions. An emergency party

was tentatively arranged to fly out and carry on if the apparatus with Dr. Baxter was intact, but on word being received that the étalon plates were smashed and the image rotator parts missing, it was clear that the optical observations must be abandoned; and since the radio observer was dependent on assistance and facilities to be provided from the rest of the expedition, that part of the programme had to be abandoned too.

OBITUARIES

Dr. Alan Baxter and Mr. John H. Strong

THE aeroplane disaster at Dakar on April 13 cost the lives of two young men of science, who were to take part in the observations of the total solar eclipse on May 20 (see p. 666).

In Dr. Baxter, the Royal Naval Scientific Service has lost one of its most valuable younger members. Born in 1910, he was educated at Manchester Central High School and the University of Manchester. He graduated with honours in mathematics and in physics, proceeded to research in microphotometry and X-rays under Prof. (now Sir Lawrence) Bragg, taking his M.Sc. in 1932 and a Ph.D. in 1935. In 1934 he joined the staff of the Natural Philosophy Department of the University of Aberdeen, later becoming a lecturer in physics. He had a conspicuous talent for perceiving the critical features of an experiment or proposed design of apparatus and a genius for simple investigation of essentials. This made him a very valuable member of the Admiralty scientific staff during the War. At Aberdeen he became interested in physical optics and astrophysics and carried out at a temporary observatory just outside the city of Aberdeen during the winters of 1937 and 1938 continuous spectrophotometric observations of the variable star Algol. The analysis of the results strongly suggested a more complex structure for Algol than a binary system; the advent of war prevented complete working out and publication of the results.

Baxter returned to Aberdeen for a time after the War, but found the Naval Scientific Service attractive to him and entered it as a permanent officer in 1946. He married in 1937 and is survived by his wife and two young daughters. He was a very welcome colleague, liked and respected, and his premature loss is deeply regretted.

Mr. John Strong was born in 1924 and educated at the Latymer Upper School and the Imperial College of Science and Technology, South Kensington. He graduated with honours in physics in 1944 and was appointed a demonstrator in the Spectroscopy and Astrophysics Department under Prof. H. Dingle and Sir George Thomson. He was carrying out research on a new type of arc source for spectroscopic analysis and was measuring the temperatures of various regions of the arc by means of the cyanogen bands. He was interested in interferometry and in astrophysics, and the eclipse observations offered excellent experience in his chosen field of research, which fitted him to be a valuable member of the observing team; and the Imperial College gladly agreed to make his services available. He was keen, energetic, eager and quick to learn.

It is particularly regrettable that what should have been valuable experience for these young men, from both of whom substantial contributions to science could confidently be expected, should have ended so tragically.

J. A. CARROLL

Mr. W. J. Bean, M.V.O., I.S.O.

IT is with deep regret that we have to record the death of William Jackson Bean, formerly curator of the Royal Botanic Gardens, Kew, who was known to every cultivator of hardy trees and shrubs by his standard three-volume work, "Trees and Shrubs Hardy in the British Isles". His death occurred on April 19 after a rather protracted illness, when within a few weeks of his eighty-fourth year. Born on May 26, 1863, in a village at the foot of the Yorkshire Wold, near Malton, his love for plant life was inherited, as for three generations his forbears had functioned as nurserymen. He was educated at Holgate School, York, and at the age of sixteen entered the famous gardens at Belvoir Castle to receive his early training in horticulture. At twenty years of age he entered the Royal Botanic Gardens, Kew, as a student gardener, and was quickly earmarked for promotion. After serving as sub-foreman in the Palm House and Orchid Houses, he was appointed foreman of the Temperate House, a position he occupied for several years before being transferred to the Arboretum as foreman in 1892.

During all this time and for several succeeding years, Bean contributed many articles to the horticultural press, chiefly *The Garden* and *The Gardeners' Chronicle*, while in 1890 he collaborated with the late William Watson in the writing of a book on "Orchids, Their Culture and Management". He was appointed assistant curator at Kew in 1900, with special charge of the Arboretum and Arboretum Herbarium. During the next few years he was sent abroad on various missions connected with arboriculture, chiefly to the United States of America and countries of Southern Europe.

At the instance of the late Sir William T. Thiselton-Dyer, Bean was entrusted with the preparation of a book descriptive of the Royal Botanic Gardens, Kew, and the work done there, which was published in 1908. It was in 1908 that he began serious work on the first two volumes of his great book on trees and shrubs, which took several years to complete; the third volume was prepared after his retirement. He also contributed many articles to the *Kew Bulletin of Miscellaneous Information*, mostly descriptive of his several journeys abroad and on new trees and shrubs. He was also a member of the committee appointed by King George V to advise on the trees in Windsor Great Park; was a member of the Floral Committee of the Royal Horticultural Society, and helped with the work of the Roads Beautifying Association from its inception.

Many honours came his way. In 1918 he was awarded the Victoria Medal of Honour by the Royal Horticultural Society, and in 1923 the same Society awarded him the Veitch Memorial Medal; later he was made an honorary member of the Society. In 1925, Bean was made a companion of the Imperial Service Order, and a few years later he received the membership of the Victorian Order for his work connected with the trees at Windsor. When Mr. Ernest Moore, the artist, was preparing for his exhibition of portraits of famous Yorkshiremen, Bean was selected as one of the number. The portrait was later purchased by Major Reginald Loder and presented

to Kew. Bean retired in 1929, since when he lived in Kew within a stone's throw of his old office, spending a good deal of time in the Gardens and Herbarium, mostly at work. In his early days he found his recreation in cricket; later he played both lawn-tennis and golf.

Personally, I feel the loss of Mr. Bean very greatly. We were associated in one capacity or another for nearly forty years. For several years I was his subordinate in the Arboretum and succeeded him as foreman. I was then transferred to the museums where we had adjoining offices, he as assistant curator, I as an assistant in the museums. Later he became curator and I keeper of museums, positions which brought us into daily contact; and throughout the whole of the time we spent together never a disagreeable word passed between us. I last saw him in September 1946, when he was far from well. He had been a widower for many years and leaves one son and one daughter, to whom our sympathy is extended.

W. DALLIMORE

Prof. B. A. McSwiney, F.R.S.

MAY I please supplement the obituary notice in *Nature* of May 3 as follows: McSwiney, a Cork man, entered Trinity College, Dublin, in 1912, and I first met him when assigned to my section of a practical class for first-year medical students. He joined the O.T.C. and in September 1915 was commissioned as a Surgeon Sub-Lieutenant R.N.V.R., and served in H.M.S. *Staunch*. He graduated in 1916 and afterwards completed his medical course and received the Sc.D. degree. In anatomy and physiology we were both grateful pupils of Prof. A. F. Dixon and Sir William Thompson. The latter was drowned when the *Leinster* was sunk in 1918. He was on his way back to his post as scientific adviser to the Ministry of Food in London. Thompson was a pioneer in the study of nutrition; he and his assistant, Dr. Caldwell, fed themselves on a rigid diet for weeks on end, performed all necessary analyses and then varied the diet and noted the changes—this asceticism on top of arduous teaching work.

W. R. G. ATKINS

WE regret to announce the following deaths:

M. Edouard Chatton, formerly professor of zoology in the University of Montpellier, *Correspondant* for the Section of Anatomy and Zoology of the Paris Academy of Sciences, on April 23.

Prof. P. L. R. Lespieau, titular member of the Section of Chemistry of the Paris Academy of Sciences, on April 21, aged eighty-two years.

Mr. G. H. Tipper, formerly of the Geological Survey of India, on April 23.

Commander H. D. Warburg, formerly superintendent of tides, Admiralty, on May 7, aged seventy-eight.

NEWS and VIEWS

Royal Society: New Foreign Members

Prof. P. Karrer

PAUL KARRER, professor of chemistry in the University of Zurich, is one of the world's leading organic chemists. A pupil of Ehrlich, his work, beginning on chemotherapeutic problems, has since ranged over a wide field of organic chemistry. In particular he has achieved outstanding success in the study of substances of biological importance, notably in the vitamin field, and his work has played a large part in the spectacular successes of organic chemistry during the last twenty years. Karrer's work on the carotenoid pigments and the structural elucidation of vitamin A has been the basis of our present knowledge of the group, and mention may also be made of his constitutional work on the structure and synthesis of vitamin B_2 (riboflavin) and the vitamins E. Notable contributions, too, have been made by him to the chemistry of plant colouring matters of the anthocyanin type, and to our knowledge of the nature and mode of action of various co-enzymes. His laboratories have for long been a centre of attraction for workers from many countries. The brilliance of his achievements was recognized in 1937 by the award of a Nobel Prize. In addition to furthering chemistry by his research, Karrer has made a notable contribution to teaching through his text-book of organic chemistry, which enjoys a world-wide reputation.

Prof. H. C. Urey

PROF. H. C. UREY is known internationally for his great contributions to physical chemistry, and for his human approach to the problems of the social implications of science. His discovery of deuterium (heavy hydrogen) in water was recognized by the award of a Nobel Prize; but most important of all, this work established his interest in the problem of isotope separation. His development of chemical exchange, distillation and other methods of separation of isotopes has enabled American firms to market such materials as N^{15} as commercial commodities. Urey was one of the first in the United States to recognize that atomic weapons could be made, and his influence was crucial in the early history of the American project. He was identified closely with development at Columbia University of the diffusion process for separation of the uranium isotopes, and he visited Great Britain in this connexion at the height of the War. The menace to civilization presented by the discovery of atomic explosives was a challenge to Urey's social conscience, and after the War he devoted himself wholeheartedly to the public dissemination of information designed to impress the problem on the people of America and the rest of the world. Since the War ended, Urey has joined the new Institute which has been established in the University of Chicago to carry out academic researches in nuclear physics.

Prof. Øjvind Winge

PROF. ØJVIND WINGE has a record of extraordinary versatility and success in genetics and cytogenetics. In his early work with the fish *Lebistes reticulatus* he established the partial sex-linkage of a large group of genes determining the male polymorphism of the species. This was the first demonstration of the genetic activity of the pairing segment of the sex chromosome. Later he established genetic

sex-determination in plants, and elucidated the nature of polyploidy. One remarkable success based on keen observation and appropriate experimentation was to demonstrate the balanced lethal situation established in the 'ever-sporting Stocks'. He has contributed much to the clarification of linkage groups in *Pisum*, and his recent work proving sexual reproduction in the yeasts is of fundamental importance for the genetics of micro-organisms.

James Alfred Ewing Medal Awarded to Sir Clifford Paterson, O.B.E., F.R.S.

On the joint recommendation of the presidents of the Royal Society and the Institution of Civil Engineers, the Council of the Institution of Civil Engineers has awarded the James Alfred Ewing Medal for 1946 to Sir Clifford Paterson, for specially meritorious contributions to the science of engineering in the field of research. The medal is awarded annually and was founded in 1936 in memory of Sir Alfred Ewing. Sir Clifford Paterson is in charge of the Research Laboratory of the General Electric Co., Ltd., Wembley, Middlesex. His contributions to the science of engineering in the field of research have extended over forty-five years. His work has been particularly outstanding in the development of new sources of illumination, in the study of their use and in their precision measurement. This work was carried out at the National Physical Laboratory until 1919 and later continued after he had joined the General Electric Co. More recently he has co-ordinated the work of numerous teams in connexion with outstanding developments in the use of high radio frequencies, thus making possible many of the vital new weapons of defence and offence. The production of special devices and particularly of new valves in quantity, at many stages of the War, kept our Services ahead of those of the enemy.

Royal Aeronautical Society Awards

The following medals have been awarded by the Council of the Royal Aeronautical Society:

Simms Gold Medal: awarded annually for the best paper read in any year before the Society on any science allied to aeronautics, such as meteorology, wireless telegraphy, instruments, to Prof. L. Aitchison, professor of industrial metallurgy, University of Birmingham;

George Taylor (of Australia) Gold Medal: awarded annually, at the discretion of the Council, for the most valuable paper submitted or read during the previous session, to Prof. A. R. Collar, Sir George White professor of aeronautical engineering, University of Bristol;

Wakefield Gold Medal: awarded annually to a member or non-member, to the designer of any invention or apparatus tending towards safety in flying, to Mr. Edwin Link, inventor of the 'Link trainer';

Society's Silver Medal: awarded, at the discretion of the Council, for an advance in aeronautical design, to Mr. W. G. Garter, chief designer, Gloster Aircraft Co., Ltd., for his work on the development and design of jet-propelled aircraft.

R.38 Memorial Prize: offered annually for the best paper received by the Society on some subject of a technical nature in the science of aeronautics, preference being given to papers which relate to airships, to Mr. J. K. Hardy, of the Royal Aircraft Establishment;

Edward Busk Memorial Prize: offered annually for the best paper received by the Society on some subject of a technical nature in connexion with aeroplanes (including seaplanes), to Mr. J. Smith, chief designer, Vickers Armstrongs, Ltd., Supermarine Works.

University of Glasgow: Freshwater Biological Laboratory and Insect Field Station

Important additions to the facilities available at the University of Glasgow for research and teaching in the field have recently been made available by the erection of two former Government huts on the shores of Loch Lomond, on a site kindly provided by Sir Iain Colquhoun, Bt., of Luss, and only some twenty miles distant from the University. The freshwater work is under the care of Dr. H. D. Slack, lecturer in freshwater biology, who has charge of one hut together with a motor-boat and dinghy. For the first time, continuous investigations can be carried out on the biology of freshwaters in Scotland, and the great size and exceptional depth of Loch Lomond render it an admirable site for such work. A generous gift of money by Sir Harold Bowden, Bt., for entomological research over a period of seven years, with particular reference to the biology of midges, is responsible for the erection and equipment of the second hut, and for the appointment of two research assistants who work under the direction of Mr. J. A. Downes, lecturer in entomology. The money is being shared with the Department of Natural History, University College, Dundee (University of St. Andrews), where the biology of *Monomorium* together with certain aspects of the midge problem are being studied by Prof. A. D. Peacock and assistants. This opportunity of co-operation between two Universities is particularly appreciated. The work of both centres is being co-ordinated with that of the Committee on the Control of Midges appointed by the Department of Health for Scotland. The Insect Field Station is also being used as a centre for the teaching of insect ecology. The University of Glasgow is thus in the fortunate position of being able to conduct field classes in freshwater biology and in insect ecology at Loch Lomond, and also to avail itself of the rapidly increasing facilities for marine biology available at the Millport Laboratory of the Scottish Marine Biological Association on the Clyde.

Further Education

It is the custom to greet a new magazine by asserting, often with more courtesy than truth, that it will fulfil a long-felt need. No such formula need apply to *Further Education*, published by the Turnstile Press, 10 Great Turnstile, London, W.C.1 (1*s.* 6*d.* monthly). The field which it covers is only beginning to be opened up, for a recognition of the need for further education too seldom troubled the education administrators of the last generation. The War did much to disclose the need and (what was more unexpected) did something to give it satisfaction. Many thousands of men and women in the Forces made their first acquaintance with 'serious pleasures', and have returned to civil life seeking the extension of that experience. The Education Act of 1944 envisaged a wide post-war enlargement of educational activity, and in its recent pamphlet, "Further Education", the Ministry set forth for the benefit of local education authorities many ideas and projects worthy of experiment and

development. By March 31, 1948, local education authorities are obliged, with minor exceptions, to submit their schemes of further education to the Ministry. Many of them have already begun, and even the backward authorities will have something to promise, if not to display, by the appointed day.

Further education may henceforth hope to enjoy something better than the status of a lesser mandated territory. But a sentimental ardour for its benefits is not enough. What are especially required during these next few years are practicable schemes, reliable progress reports, and a brisk exchange of ideas. The first number of *Further Education* reveals a realistic purpose in providing these requirements, and is not afflicted by that sense of piety which so often besets ventures which want to advance human progress. In writing or talking about further education it is better to be hard-boiled than half-baked, and one of the characteristics of this new magazine is its preoccupation with ways and means. Its editor, Mr. J. Mackay Mure, is a fervent educationist, and his management of the paper's policy is an assurance that it will keep both feet on the ground. From the first number, it is plain that he intends to take full advantage of the terms of reference embodied in the paper's title. Further education has as much to do with vocational training as with the pursuit of culture, and the more we can be led to considering them as part of a common way of life the sooner shall we discern their relevance to each other. One final merit of this new monthly must be mentioned, and that is the lively quality of most of its articles. Nowhere has the boll-weevil of jargon made greater ravages than in educational journalism, and it is a welcome relief to find it entirely absent from these pages.

The Ray Society

THE annual general meeting of the Ray Society, now in its hundred and third year, was held on March 21. During the past year the Society lost by retirement owing to ill-health the services of its two senior officers, Sir Sidney Harmer, president since 1931, and Dr. W. T. Calman, secretary since 1919. Resolutions were passed unanimously thanking them for their distinguished services to the Society. Prof. F. E. Weiss having expressed the wish to retire from the office of honorary treasurer, his resignation was accepted with regret. Mr. A. D. Cotton resigned as vice-president. It was announced that Dr. Ben Dawes' volume on "The Trematoda of British Fishes" is ready for distribution, and, owing to the greatly increased costs of publication, this will form the issue to subscribers for the two years 1944 and 1945. The volume for 1946 will be Dr. Berrill's volume on "British Tunicates", but unexpected difficulties have caused delay in sending this work to press. A volume on Pennant's travels in Europe, edited by Prof. G. R. de Beer, is, however, nearly ready for press, and other works on a wide variety of subjects relating to the natural history of the British Isles are in active preparation. The following were elected officers and new members of council: *President*, Prof. G. R. de Beer; *Hon. Treasurer*, Mr. A. C. Townsend; *Hon. Secretary*, Dr. Errol I. White; *Vice-presidents*, Prof. F. E. Weiss, Mr. M. A. C. Hinton, Mr. E. R. Martin and Lieut.-Colonel Seymour Sewell; *Members of Council*, Mr. A. H. G. Alston, Dr. J. W. Evans, Mr. H. R. Hewer, Dr. George Taylor and Mr. Brian Vesey-Fitzgerald.

New British Ornithological Magazine

THE first issue of the new *Wild Birds Magazine* has appeared as a bi-monthly (until the paper ration increases) under the editorship of Mr. Eric Hardy and published from Friars Lodge, Friars Lane, Richmond, Surrey. There are illustrated articles dealing with bird-life at Manchester sewage farm (L. L. Turner), observations at the Yorkshire Naturalists' Union's new bird ringing and observation station at the Spurn by J. Lord, on a heronry (F. A. Lowe), birds of North Devon (N. V. Allen), Dungeness shingle (R. B. Burrowes), etc., while field notes include the first Lancashire record of the European bee-eater (*Merops apiaster*) in the autumn 1946, and the red-backed shrike using the same nesting site in two successive years. An abnormal immigration of waxwings and great grey shrikes into England during the recent winter is noted.

Industrial Uses of Methane

A PAMPHLET entitled "Chemicals from Methane", by Dr. J. P. Lawrie (pp. 24. Science Services, Ltd., 255 Russell Court, London, W.C.1, 1947. 3*s*.), deals with possible uses of methane from natural gas which, it is said, is available in important quantities in Great Britain. It is pointed out that large quantities of carbon black are imported from the United States, much of which is made there from natural gas, and it is suggested that this might well be made from native gas. Coke-oven gas is also rich in methane. Other products which might be obtained from methane, according to patent literature quoted, are hydrogen for ammonia synthesis, acetylene by exposure to an electric arc, methyl chloride by chlorination, hydrogen sulphide by reaction with sulphur, oxidation products such as methanol, formaldehyde, and formic acid, and nitromethane. A short bibliography is given.

Royal Institution

At the anniversary meeting of the members of the Royal Institution held on May 1, the following officers were elected: *President*, Lord Rayleigh; *Secretary*, Prof. A. O. Rankine; *Treasurer*, Dr. R. E. Slade; *Managers*, Prof. E. N. da C. Andrade, Mr. M. G. Bennett, Prof. H. V. A. Briscoe, Major W. H. Cadman, Sir John Craig, Dr. C. H. Desch, Sir Alfred Egerton, Dr. E. V. Evans, Dr. W. Jevons, Colonel E. E. B. Mackintosh, Mr. G. S. W. Marlow, Prof. L. C. Martin, Sir Richard Paget, Sir Clifford Patterson, Sir Geoffrey Taylor; *Visitors*, Mr. J. J. Abraham, Mr. W. E. Watson Baker, Dr. J. H. Brinkworth, Mr. D. I. Duveen, Mr. F. P. Dunn, Mr. P. Evans, Dr. A. T. Fraser, Sir William Halcrow, Prof. F. L. Hopwood, Mr. L. B. W. Jolley, Mr. D. Northall-Laurie, Dr. E. Talbot Paris, Sir Harry Railing, Prof. D. V. Thompson, Prof. H. E. Watson.

Physical Society: Election of Officers

THE following have been elected officers for 1947–48 of the Physical Society: *President*, Prof. G. I. Finch; *Vice-Presidents*, Sir Edward Appleton, Mr. A. J. Philpot, Prof. H. R. Robinson, Dr. W. D. Wright; *Hon. Secretaries*, Dr. W. Jevons, Dr. H. H. Hopkins; *Hon. Foreign Secretary*, Prof. E. N. da C. Andrade; *Hon. Treasurer*, Dr. H. Shaw; *Hon. Librarian*, Dr. R. W. B. Pearse; *Members of Council*, Dr. W. S. Stiles, Dr. C. H. Collie, Prof. J. D. Bernal, Dr. D. Roaf, Dr. A. C. G. Menzies, Prof. R. E. Peierls, Dr. F. C. Toy, Prof. J. F. Allen, Mr. J. H.

Awbery, Prof. L. F. Bates, Dr. R. C. Evans, Dr. C. E. Wynn-Williams.

The officers for 1947-48 of the four Groups of the Society are as follows: Colour Group: *Chairman*, Mr. J. G. Holmes; *Hon. Secretary*, Dr. W. D. Wright; Optical Group: *Chairman*, Prof. L. C. Martin; *Hon. Secretary*, Mr. E. W. H. Selwyn; Low-Temperature Group: *Chairman*, Sir Alfred Egerton; *Hon. Secretary*, Mr. G. G. Haselden; Acoustics Group: *Chairman*, Mr. H. L. Kirke; *Hon. Secretaries*, Mr. W. H. Allen and Mr. A. T. Pickles.

University of Glasgow: Appointments

THE following appointments in the University of Glasgow have been announced: Prof. G. W. Wishart, professor of physiological chemistry, is to become director of post-graduate medical education. Mr. J. R. Anderson has been appointed lecturer in pathology; Dr. W. F. Anderson, lecturer in materia medica; Dr. J. C. D. Brand (of King's College, London), lecturer in chemistry; Dr. S. A. Hutchinson (formerly with the Distillers' Co., Ltd.), lecturer in botany; and Mr. A. C. Robb, Nuffield research assistant in physics.

Congresses

International Conference on the Emission from the Aurora and the Night Sky

AN international conference to discuss the emission from the aurora and the night sky is being arranged under the auspices of the Gassiot Committee of the Royal Society. This will be held in London during July 7–11 at the rooms of the Royal Society at Burlington House.

Conference on the Strength of Solids

A DETAILED programme has now been prepared of the Conference on the Strength of Solids to be held at the H. H. Wills Physical Laboratory, University of Bristol, during July 7–10 (see *Nature*, Feb. 8, p. 193). The topics to be discussed include hardening of metals by internal oxidation (J. L. Meyering, Eindhoven), rate of approach to the ordered state in alloys (M. Weil, Grenoble), mechanical properties of metals at low temperatures (Prof. M. J. Druyvesteyn, Delft), creep in metals (Prof. E. N. da C. Andrade, Dr. E. Orowan and Dr. B. Chalmers), recovery and recrystallization (Prof. W. G. Burgers, Delft), hardness and crystal size (Sir Lawrence Bragg), thermo-electric methods of studying diffusion (C. Crussard, Paris), internal friction in metals (Prof. L. Guillet, Paris), elastic after-effects in iron (Prof. H. B. G. Casimir, Eindhoven) and sintered artefacts (J. H. McKee).

Nuclear Physics in Biological and Medical Sciences

THE University of California Medical School, in association with University Extension, University of California, has arranged a course in the application of nuclear physics to the biological and medical sciences. This course will be given at the Medical Center, San Francisco, during June 30–July 18. There will be lectures, laboratory demonstrations and seminars for round-table discussions. The course is open to those interested in the field of medical and biological research. The first week will be devoted to lectures, etc., on the general subject, the second week to the radioactive 'tracers' in biology and medicine and the third to therapeutic and diagnostic aspects of 'tracer' elements. Detailed information can be obtained from Dr. Stacy R. Mettier, head of the Post-graduate Instruction Medical Extension, University of California Medical Center, San Francisco 22, California.

Industrial Utilization of Agricultural Products and of Seaweed

A Colloquium on the Industrial Utilization of Agricultural Products and of Seaweed, arranged by the Irish Chemical Association and the Dublin Section of the Royal Institute of Chemistry, will be held in the Department of Chemistry, University College, Dublin, on July 2 and 3. The meetings will be opened by the Minister for Industry and Commerce of Eire, and the first session will be a general survey opened by Prof. J. L. Simonsen, director of the Colonial Products Research Council, London, who will speak on "Agricultural Products and the Chemical Industry". The second session, on seaweed, will be opened by Prof. J. B. Speakman, professor of textile industries, University of Leeds, with a paper on "The Production, Properties and Uses of Seaweed Rayon". The third session will deal with carbohydrates, and will be opened by a paper by Prof. E. L. Hirst, Sir Samuel Hall professor of chemistry, University of Manchester, on "The Utilization of Carbohydrate Products". On July 3, there will be a Government reception at Phœnix Park, Dublin.

Announcements

SIR ROBERT ROBINSON, Waynflete professor of chemistry in the University of Oxford, and Prof. P. Karrer, professor of chemistry in the University of Zurich, have been elected *Correspondants* for the Section of Chemistry of the Paris Academy of Sciences. Sir Robert Robinson has also recently been elected a foreign member of the Royal Norwegian Academy of Sciences.

A CONVERSAZIONE of the Royal Society is being held at the Society's rooms on May 29 at 8.30 p.m.

MR. J. DAVIDSON PRATT, director and secretary of the Association of British Chemical Manufacturers, has been awarded by the American Government the Medal of Freedom with silver palms for exceptionally meritorious work and co-operation with the United States while Controller of Chemical Defence Development at the Ministry of Supply during 1940–45.

THE Ministry of Supply announces the following appointments to the Minister's Advisory Council on Scientific Research and Technical Development: Prof. Wesley Austin, Goldsmith's professor of metallurgy in the University of Cambridge; Prof. W. E. Curtis, professor of physics at King's College, Newcastle; Lord Hankey; Prof. Willis Jackson, professor of electrical engineering at the Imperial College of Science and Technology, London; Prof. E. K. Rideal, Fullerian professor of chemistry at the Royal Institution; Mr. S. Robson, of the Imperial Smelting Corporation of Bristol.

DR. E. C. AMOROSO, reader in histology and embryology at the Royal Veterinary College, London, has been appointed to the chair of veterinary physiology in the College.

ERRATUM. In the communication "Phase-Contrast in the Photomicrography of Metals", in *Nature*, May 10, p. 639, par. 6, for "42-mm. oil immersion" read "2-mm. oil immersion".

LETTERS TO THE EDITORS

The Editors do not hold themselves responsible for opinions expressed by their correspondents. No notice is taken of anonymous communications

Discovery of a New Skull of the South African Ape-man, *Plesianthropus*

BETWEEN 1924, when the Taungs ape-man was discovered, and 1941, when the jaws of the baby Kromdraai ape-man were found, remains of many individuals of this wonderful family, which some of us consider to be nearly related to man, were discovered; sufficient to show that in South Africa we may have the key which will solve the problem of the origin of man. But from 1941 until a few months ago, no further research was undertaken.

In 1946, a book was published on all we know of the South African ape-man; and the world awoke to the possibilities of the wonderful results that might be achieved by the further study of our caves. The United States has come to realize that South Africa is a more promising centre for the solution of the problem than even Java or China; and she seems determined to see that the problem must be solved, and solved soon.

At the beginning of this year, at the special request of General Smuts, I again started to hunt for more 'missing links'. My assistants and I commenced work at Kromdraai and continued there for three months. We found many interesting remains, including a very fine skull of a sabre-tooth tiger (*Megantheron*) and the skull of a large type of 'baboon', which belongs to a new genus; but only one bone that had possibly belonged to an ape-man.

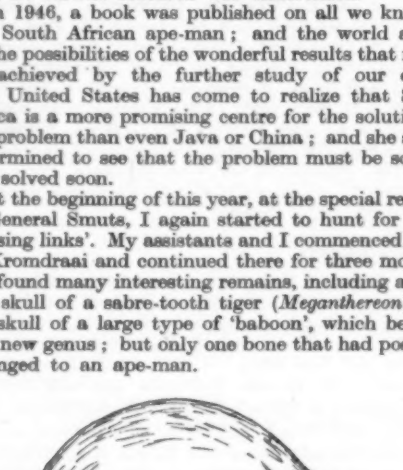


FIG. 1. SIDE VIEW OF SKULL OF OLD FEMALE STERKFONTEIN APE-MAN *Plesianthropus transvaalensis* (BROOM). ½ NATURAL SIZE. THE LOWER PART OF THE OCCIPUT AND PART OF THE JUGAL ARCH ARE STILL EMBEDDED IN MATRIX, AND THE LOWER JAW IS NOT PRESENT

Then on April 1 we started work at Sterkfontein, and almost immediately our labours were rewarded by sensational discoveries. On April 8 we found an isolated crushed snout of an adolescent *Plesianthropus* with some beautiful teeth; and a fragment of a snout of a child of possibly three years. This showed the perfect upper milk molars, and a note on the discovery was sent to *Nature* [see issue of May 3, p. 602. Editors]. On April 11 two quite isolated teeth of Sterkfontein apes were found—one the beautiful upper canine of a male of perhaps thirty years, and a lower molar probably of a female of forty years.

But on April 18 a small blast cracked open a block of breccia, and there in the middle lay a perfect skull without the mandible of an adult *Plesianthropus*, with the brain case broken across. In ten days we had found the remains of five—possibly six—individuals of the Sterkfontein ape-man, *Plesianthropus*, and one of them represented by a complete skull.

FIG. 2. FRONT VIEW OF SKULL OF OLD FEMALE STERKFONTEIN APE-MAN, *Plesianthropus transvaalensis* (BROOM). ½ NATURAL SIZE

The bones are very friable and the matrix not only rather hard lime, but also breccia with many large broken pieces of chert; it will take many weeks before the skull can be completely developed from the matrix.

Enough, however, has now been done to reveal most of the more striking features of the skull. In the type skull the brain cavity was filled with matrix. In the newly discovered skull there is only a lining of lime crystals from about ½ in. to nearly ¼ in. in thickness. When this layer is removed we will have every detail of the anatomy of the inner side of the base of the skull. The under surface of the base of the skull appears to be just as perfect; but it will take some further weeks of preparation to reveal it all.

So far, our labours have been concentrated on the details of the face, and in cleaning the cranial vault. The teeth are all lost, but many sockets remain, and we can say with much confidence that the skull is that of an elderly female.

The drawings I give will serve to show the general aspect of the face and the side view. I think there will be very general agreement that the being is not a chimpanzee or even closely allied to any of the living anthropoids, and that, though small, the skull has many resemblances to that of man.

The skull from glabella to opisthocranion is about 150 mm., and the greatest parietal width is about 100 mm. It is thus seen to have an index of about 66, and to be extremely dolichocephalic. As yet, we can only give a roughly approximate size for the brain cavity, but it seems probable that it will be about 500 c.c.

Of course, it will take many weeks before the skull is completely worked up and a full account can be published, but it seems well that the world should know that such a valuable skull has been discovered.

R. BROOM

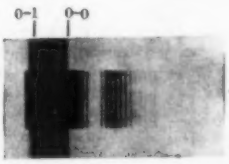
Transvaal Museum,
Pretoria.
April 2.

Active Oxygen

THE light of the night sky has excited increased attention since the end of the War; from the practically minded student of rockets and from astronomers, as well as from students of the upper atmosphere. The astronomer is particularly interested because of the effect of this radiation on his observations. To the student of the upper atmosphere, this radiation has held out a promise of information concerning the composition of the upper air, as well as concerning fundamental processes there. Because of the difficult problem presented by spectroscopy of the light of the night sky, there are still many unidentified radiations in its spectrum, as well as inadequately studied regions. In every review of the contributions of spectroscopy to the study of the upper atmosphere, attention is directed to the desirability of further laboratory investigations of the spectra of O_2 and N_2, and the desirability of obtaining emission spectra of ozone and the oxides of nitrogen. It has been suggested that a search along these lines may yield a satisfactory identification of the strong ultra-violet band at λ3556 A.

These facts, and some recent observations by Stebbins, Whitford and Swings[1] at Mt. Wilson on one hand, and by R. Herman, L. Herman and J. Gauzit[2] at the Lyons Observatory on the infra-red spectrum of the night sky on the other, led me to an extended study of the auroral afterglow in the infra-red. A particularly good nitrogen auroral afterglow at very low pressures was studied, and in time the intensity of the afterglow went down considerably, because of the decrease in pressure which resulted from the clean-up of the nitrogen. It was found that under these conditions the addition of relatively small quantities of oxygen restored the intensity of the afterglow in a very effective manner. This suggested that increasing the amount of oxygen might lead to interesting results, and this was done. It should be mentioned first that the neutral oxygen molecule does not readily show an emission spectrum. A part of the main absorption system observed by Schumann has been observed in emission by Runge, and hence the name Schumann–Runge bands for these famous ultra-violet bands. Hopfield reported an emission spectrum in the region below λ 2218 A. consisting of a single progression. Other band systems, much too few in number and all consisting of transitions from the ground state to low-lying metastable states, have been observed in absorption in gaseous and liquid oxygen. The most famous of these are the so-called atmospheric bands, $A^1\Sigma \leftarrow X^3\Sigma$, observed in atmospheric absorption (especially the solar spectrum), and also observed in the laboratory by absorption through pure oxygen. It is this system which has now been observed for the first time in emission in the afterglow in oxygen, which resulted from the above procedure.

The name 'active oxygen' will be used to identify this phenomenon, just as the name 'active nitrogen' was given to the similar phenomenon in nitrogen.



SPECTRUM OF ACTIVE OXYGEN

The spectrum of the afterglow of active oxygen which is reproduced shows two members of the atmospheric system of oxygen, which are readily identified as 0–0 and 0–1 by comparing them with the first positive system of nitrogen which is superposed. Using hypersensitized Eastman *IN* plates, it is easy to obtain a good spectrogram in a time equal to that necessary for the nitrogen afterglow. It is quite likely that further studies of this afterglow will aid in the study of the physics of the upper atmosphere.

J. KAPLAN

University of California,
Los Angeles, California.
Feb. 14.

[1] Stebbins, Whitford and Swings, *Astrophys. J.*, **101**, 39 (1945).
[2] Herman, R., Herman, L., and Gauzit, J., *Nature*, **156**, 114 (1945).

Structure of 'Terylene'

ARISING from the recent communication by Prof. W. T. Astbury and Mr. C. J. Brown[1] concerning the structure of 'Terylene', we wish to place on record the earliest investigation of its structure by the X-ray method. The results recently reported by Astbury and Brown from work done in 1944 are in general agreement with those which we obtained some two years earlier.

Early in 1942, the Controller of Chemical Research, Ministry of Supply, learned of the work of Mr. J. R. Whinfield and Dr. J. T. Dickson (of the Calico Printers' Association, Ltd.) on polyethylene terephthalate[2], and requested the Chemical Research Laboratory, D.S.I.R., to assist in its further development. As a result, almost the first step taken was to arrange for the National Physical Laboratory to carry out an X-ray examination of various 'Terylene' samples supplied by Mr. Whinfield and Dr. Dickson; this work was completed by July 7, 1942.

The granular powder produced by cooling a nitrobenzene solution of 'Terylene' gave the pattern shown in Fig. 1. The well-defined system of rings, corresponding to lattice-spacings of 10·5, 5·4, 5·0, 4·1, 3·9 and 3·4 $\times$ 10^{-8} cm., indicates that the material is definitely crystalline in the sense that neighbouring molecular chains bear a regular spatial relation to each other.

Slow cooling of molten 'Terylene' produces an opaque material which gave the pattern shown in Fig. 2. This is identical with Fig. 1, though the rings are somewhat sharper. The material has therefore the same structure, and the greater sharpness may be due to a larger particle size.

When molten 'Terylene' is shock-cooled, a translucent product is obtained; this gave the pattern shown in Fig. 3, which contains two diffuse haloes. The inner halo corresponds to the inner ring (spacing 10·5 A.) of the previous forms. The outer halo corresponds to the outer group of diffraction rings of the previous forms; the rings have diffused together to form a broad halo. The molecular structure is therefore a heavily distorted form of the regular structure shown by the previously described crystalline forms.

Shock-cooled filaments may be cold-drawn into 'Terylene' fibres, and these gave the pattern shown in Fig. 4. This shows that very pronounced orientation of the molecules along the length of the fibre has taken place, the orientation being complete to within about 5°. The orientation is indicated by the con-

Fig. 1 Fig. 2

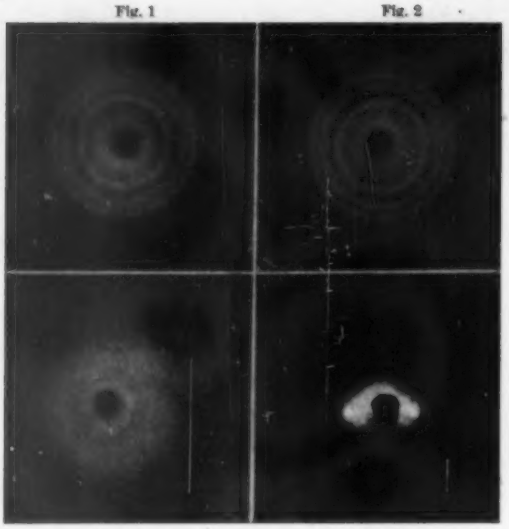


Fig. 3 Fig. 4

centration of the intensity of the rings to a few points on the circumference. The diameters of the rings, on which the intensity maxima are formed, are the same as the diameters in the previous crystalline forms, indicating that the basic molecular structure is the same. It will be seen that the maxima are not so sharp as the rings shown, for example, in Fig. 2; in aligning the molecules along the length in cold-drawing, some of the distortion marking the shock-cooled material is retained.

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D. V. N. Hardy
W. A. Wood

Chemical Research Laboratory,
and
National Physical Laboratory,
Teddington.
Feb. 14.

[1] *Nature*, **158**, 871 (1946).
[2] Whinfield, J. R., *Nature*, **158**, 930 (1946).

Electrical Conductivity of River, Rain and Snow Water

"The Data of Geochemistry", by the late F. W. Clarke, is a mine of information on river waters, their variation with geological formation and Joly's 'cyclic sodium' transported in the air and brought down by rain. These phenomena are simply studied by measurements of electrical conductivity at 0° C. Thus $C \times 10^6$ for Plymouth tap-water varied during 1923–24 from 25 to 28; the values found on July 7, 1923, and September 26, 1923, were 27 and 28—identical respectively with those of July 5, 1945, and September 19, 1945. The *p*H varied from 6·4 to 6·8 during the year. It was with some surprise that I found rain-water, collected at Downderry on the Cornish coast during a downpour on March 12, 1946, to have a conductivity 24, with *p*H 6·6. Rain at Plymouth on March 13, 1946, had conductivity 55 and *p*H 4·0. During the night of September 19–20, 1946, rain at Antony, Cornwall, had conductivity 28, the typical September figure for Dartmoor water. Clean snow at Downderry on January 24, 1947, gave 44, and a Plymouth sample of January 25, 1947, gave 72 for conductivity. The latter was taken from the middle of the snow blanket and was, on thawing, surprisingly sooty. Plymouth rain of January 8, 1947, had conductivity 70, close to that of snow.

The country rain samples, with conductivities 24 and 28, had come with south-westerly air, clean from the sea. Thus Dartmoor water derives almost all its electrolytes from sea-salt, but contains from 3·1 to 3·5 parts per million of silica, and colouring matter equivalent to 0·26–0·40 p.p.m. of the yellowish tint given in the silica reaction. The conductivity of water from a calcareous source is about ten times as great. On diluting sea water with 'conductivity water' of conductivity 1 or less, a curve was obtained relating dilution to conductivity and showing that country rain represents sea water diluted to rather less than 1 in 2,000. The purest British natural water met with was the Aberystwyth town supply, conductivity 19.

Early in July 1945, however, samples of river water were flown to Britain from Ceylon. These were astonishingly pure and gave conductivities 10–20. The error due to solubility of the glass appeared to be negligible, and the purest sample corresponded to sea water diluted slightly less than 1 in 5,000. Since the sea water from the English Channel had salinity 35·2‰, or chlorine 19·4‰, the purest sample, with conductivity 10, contained 3·9 parts per million chloride. The amounts may seem small; but it should be remembered that phosphate in natural waters is reckoned in parts per hundred or per thousand million, and upon these traces the production of all water-living organisms depends.

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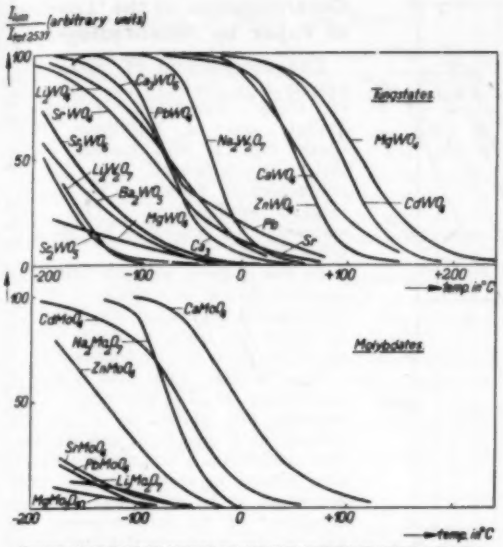
March 12.

Fluorescence of Tungstates and Molybdates

The tungstates of calcium, strontium, magnesium and zinc, and the molybdates of calcium are known to show luminescence upon excitation by cathode rays or short-wave ultra-violet radiation. It is commonly assumed that this luminescence is characteristic of the tungstate and molybdate groups. If this is true, there must be a reason why other tungstates and molybdates are found to be non-luminescent. Studying a number of different tungstates and molybdates in this Laboratory, we have found this reason to be the temperature-quenching.

Tungstates and molybdates of zinc, magnesium, cadmium, calcium, strontium, barium, lead, lithium and sodium have been prepared by the following method. Oxides or carbonates of the elements mentioned were mixed in stoichiometric proportion with tungstic or molybdic acid and a little water. The mixture was dried on a water bath and fired at temperatures below the melting point of the particular system, but high enough to guarantee good crystallization. These temperatures varied between 530° for lithium molybdate to 1,100° for most of the tungstates. One sample of magnesium tungstate was heated to a higher temperature (1,300° C.) in order to obtain the high-temperature α-form[1].



TEMPERATURE-DEPENDENCE OF THE FLUORESCENCE OF TUNGSTATES AND MOLYBDATES FOR EXCITATION BY λ 2537 A. (MAXIMA ARBITRARILY FIXED AT 100-LEVEL). (THE MODIFICATION OF MAGNESIUM TUNGSTATE THAT IS QUENCHED AT LOW TEMPERATURES IS THE α-FORM)

Nearly all substances investigated show fluorescence at a low temperature upon excitation by λ 2537 A. (see graph). The temperature-range in which quenching occurs is different, not only for compounds of different composition, but also for the same compound in different modifications (α- and β-magnesium tungstate). For the few tungstates for which no luminescence was found, the quenching range is probably situated beyond −180° C., so that fluorescence may be expected at extremely low temperatures. The quenching-ranges of tungstates are, on the whole, at higher temperatures than those of the molybdates. This explains why many more tungstates than molybdates are known to show luminescence.

A more complete report of our investigations, including measurements of absorption and fluorescence spectra, is to be published elsewhere[2].

F. A. KRÖGER

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Eindhoven.
Feb. 21.

[1] Hüniger, cited by Birus, K., *Ergeb. Exakt. Naturw.*, **20**, 221 (1942). Hill, C. G. A., *Trans. Farad. Soc.*, **42**, 666 (1946).
[2] Kröger, F. A., "Some Aspects of the Luminescence of Solids" (Elsevier Publishing Co., Amsterdam and New York, 1947), in the press.

Gas Discharge in Air of Atmospheric Pressure at Very Low Voltage

IT has been observed that a potential difference of as little as 15 V. applied between two semi-conductors in contact with each other, or alternatively, of a semi-conductor in contact with a metal, may sustain a gas discharge in air of atmospheric pressure.

The semi-conductors used were grains of pale green carborundum, selected for paleness from commercial No. 8 mesh samples. The grains were either stuck with solder into metal holders, or laid on a hardened and polished steel block and a second similar block laid on top of the grain. The potential was taken from the sliding contact of a low-impedance potentiometer across D.C. mains and measured by means of an ordinary voltmeter.

The gas discharge was of a pale bluish-mauve colour, and if viewed through a low-power microscope was seen to consist of streamers from grain to grain (or grain to steel block) near the point of contact. The streamers were several microns long.

The phenomenon could not be observed in every case. The potential range at which it would occur is from less than 15 V., but more than 13 V. to about 50 V. At higher potentials the contact area would as likely as not become incandescent and, therefore, so highly conductive that equipotential surfaces in the crystal would move outwards, bringing the areas of the crystal where the potential difference across the gap reaches 15 V. into regions where the air-gap becomes too wide.

A phenomenon like this was expected to occur only in the immediate neighbourhood of the contact, that is, where the air-gap was comparable with the mean free path of gas molecules. Where in fact it occurs, the path along the streamer contains many hundred mean free paths, and it is therefore believed that radiation from streamer to streamer plays an essential part in the excitation mechanism.

Bay and Szigeti[1] described luminous phenomena on carborundum crystals. Similar phenomena were also observed by me. They are apparently due to incandescence at the point of contact and occur if the current is allowed to build up to values in excess of those at which gas discharges can occur. Light travelling from the incandescent zone inside the crystal emerges from its whole surface and gives the appearance of the whole crystal being luminous. As the light is due to the incandescence of a substance which disintegrates below 2,000° K., and which radiates rather like a black body, it is originally of a yellow tinge. After transmission through a more or less coloured crystal, it emerges filtered sometimes as a pure white and sometimes as a brilliant yellow. The bluish-mauve colour of the gas-discharge described above has never been observed to emerge from the mass of the crystal. There is also no low-voltage limit for sustaining this mass glow once it has been initiated.

My observations are now some years old. Pressure of other work has since, and will presumably in the future, prevent my following the matter up further.

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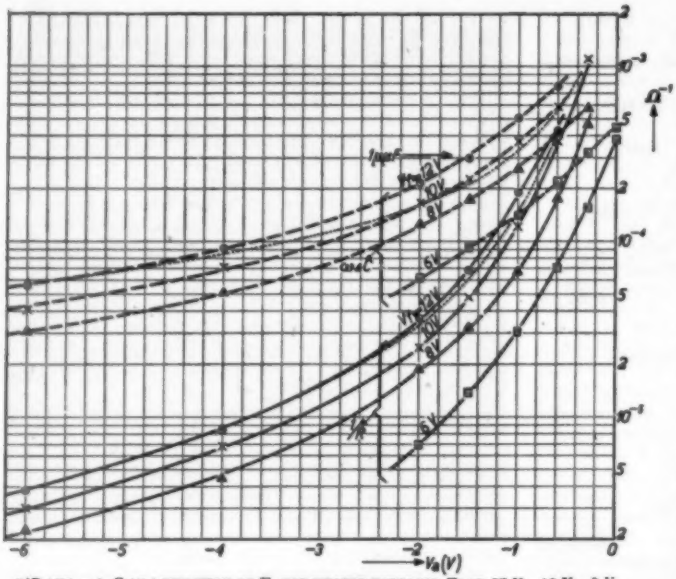
[1] U.S. Patent No. 2,254,957, September 2, 1941, and an earlier Hungarian patent of October 23, 1939.

Total Emission Damping in Diodes

A FEW months ago, C. N. Smyth[1] published preliminary results on a new source of energy loss in space-charge-limited diodes at high frequencies. This energy loss was due to the space-charge between the electrodes, and hence it was called 'total emission damping'; it is a transit time effect occurring at ultra-high frequencies only. The same effect was observed a few years ago at this Laboratory at about 100 Mc. After reading Mr. Smyth's communication we took up this subject again.

We carried out measurements at 5·8 m. wavelength on a diode having an emitting cathode area



$1/R$ AND $\omega\Delta C$ AS A FUNCTION OF V_a FOR HEATER VOLTAGES V_f OF 12 V., 10 V., 8 V. AND 6 V. RESPECTIVELY

of about 10 cm.² and an anode–cathode distance of 0·1 cm. The results are shown in the accompanying graph, in which the conductive part $1/R$ (full lines) and the reactive part $\omega\Delta C$ (broken lines) of the additional admittance due to the space-charge between anode and cathode is plotted against the anode voltage V_a (not corrected for contact potentials) with the heater voltage V_f as a parameter (heater voltage $V_f = 12$ V., 10 V., 8 V. and 6 V. respectively).

The graph also shows the dotted curves $C_1 V_a^{-1}$ (upper curve) and $C_2 V_a^{-2}$; the constant C_1 is chosen so that the first curve coincides with the curve $\omega\Delta C$ (for $V_f = 12$ V.) at $V_a = -6$ V., the constant C_2 so that the second curve coincides with the curve $1/R$ (for $V_f = 12$ V.) at $V_a = -6$ V. These curves indicate that $\omega\Delta C$ and $1/R$ are approximately proportional to V_a^{-1} and V_a^{-2}, respectively. $\omega\Delta C$ and $1/R$ are only slightly dependent upon the saturation current of the cathode. Taking the saturation current at $V_f = 6$ V. as a unit, we measured at $V_f = 8$ V., 10 V. and 12 V., saturation currents of 14, 140 and 1,100 units, respectively. This shows that a change in saturation current by a factor 100 only results in a change in $\omega\Delta C$ and $1/R$ by about a factor 3 or less. It would be expected from a theoretical point of view that the dependence of $\omega\Delta C$ and $1/R$ upon the saturation current will be more pronounced if either the cathode–anode distance or the saturation current is smaller (compare the curves for $V_f = 6$ V. and $V_f = 8$ V.).

It is also to be expected from a theoretical point of view that ΔC would scarcely depend on frequency, and that $1/R$ would be proportional to ω^2, except for the highest frequencies.

A full account of our investigations will be published elsewhere.

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N. V. Philips' Gloeilampenfabrieken,
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Feb. 13.

[1] Smyth, C. N., *Nature*, **157**, 841 (1946).

Determination of the 'Loading' in Paper by Microradiography

THE development of microradiography as a result of the researches of Goby, Dauvillier, Lamarque, Trillat, and of Maddigan, Ball, Clark, etc., is well known. The latter recommended the use of characteristic radiation for metallurgical applications. One may endeavour to generalize his ideas in other fields.

In this respect, we have been able to show that it is possible to obtain information regarding the 'loading' in paper by using a characteristic radiation (iron $K\alpha$, or copper $K\alpha$).

The 'Metalix' tube used is run at a tension of 25 kilovolts. The samples are placed in a circular camera at 2 cm. from the window. The emulsion is a Lippmann-Gevaert film placed in direct contact with the sheet to be examined. For an intensity of 15 milliamperes, the time of the exposures did not exceed five minutes. After development, the image was enlarged by a microscope with a photographic camera.

Figs. 1 and 2 correspond to bisulphite papers with 'loadings' of different natures amounting to 10 per cent. The 'loading' appears in white, and the initial enlargement is of a range of 125 diameters. A comparison between the photographs shows the interest of the method.

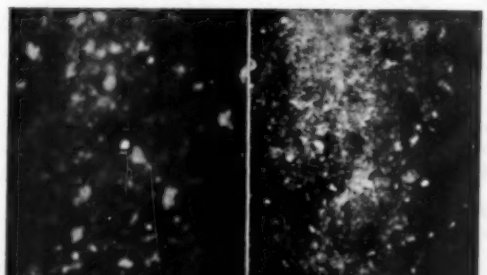

Fig. 1 Fig. 2

We have taken microradiographs of many samples of paper 'loaded' with different materials (titanium oxide, kaolin, etc.) at different concentrations. With characteristic radiation it is possible to control the loading in paper and even to determine approximately its proportion[1]. In order to obtain information regarding the actual fibres, it is necessary to use a greater wave-length (for example, chromium $K\alpha$) or a low-voltage tungsten tube.

The above investigation was carried out for the Fonds du Centenaire de l'A.I.Lg.

H. J. LAMBOT

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University of Liège.

[1] Lambot, H. J., *Bull. Soc. Sci. Liège* (1946).

Equivalence of Mass and Energy

THE following describes an ideal experiment from which the law of equivalence of mass and energy may be derived by using means employed in elementary physics.

Suppose a cylindrical tube entirely evacuated at the ends of which mirrors μ_1 and μ_2 are placed perpendicular to the generating line of the cylinder, and let the coefficient of absorption of μ_1 and μ_2 be zero. A ray of light perpendicular to the mirrors will be therefore reflected from μ_1 and μ_2 for an indefinitely long time.

Consider a monochromatic ray composed of photons, the mass of each photon being m and the velocity of each being c (in vacuum). The impulse of each photon is therefore equal to mc, and after reflexion it reverses its direction only, if we assume that photons have absolute elasticity (an assumption made, for example, in the Compton effect).

Applying the method used in the elementary kinetic theory of gases, we get

$$p = 2mc \cdot N \cdot \frac{c}{2a} \cdot \frac{1}{S},$$

where p signifies the mean pressure of a bundle of parallel rays on one of the mirrors, N is the total number of photons in the tube, a is the length of the tube, and S is its area of cross-section.

Substituting the volume V for aS,

$$pV = mc^2N.$$

An infinitesimal parallel displacement of one mirror towards the other will diminish the volume of the tube by dV. The amount of work done by this displacement is pdV. Evidently, this amount is equal to the energy increase of the 'photonic gas', or of all its N photons together.

Differentiation of the preceding formula gives

$$p \cdot dV = c^2N \cdot dm,$$

since the number of photons does not change and the velocity c (according to a postulate of the theory of relativity) remains unchanged too.

Indicating by dE the energy increase of each photon, we get

$$\frac{p\,dV}{N} = dE = c^2dm.$$

Moving the mirrors towards each other by a finite distance and integrating, we get

$$E - E_0 = c^2(m - m_0);$$

or

$$E - mc^2 = E_0 - m_0c^2 = \text{constant},$$

for any pair of values of E and m.

Hence

$$E = mc^2 + \text{constant}.$$

Since an expression of energy leaves an additive constant free, we may so choose the latter that

$$E = mc^2.$$

The above proof of this fundamental formula applies, of course, only to the special case of the energy of photons.

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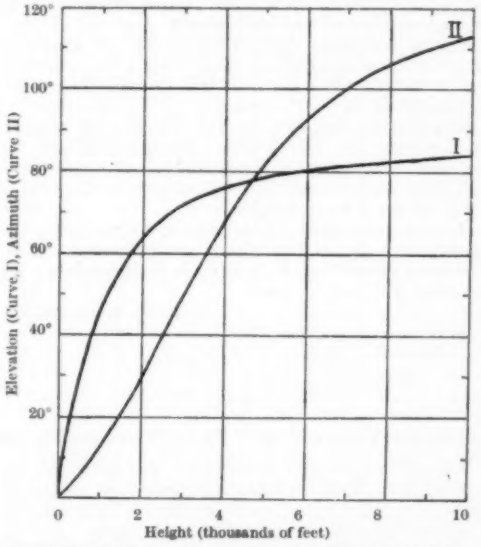
An Azimuthal Method of Measuring Cloud Height with a Searchlight

THE normal method of determining the height of the cloud base at night is to direct a vertical searchlight beam on to the cloud and measure the angle of elevation E of the spot of light from a point at a known horizontal distance L from the searchlight. The height h of the cloud base is then given by $h = L \tan E$. The length L of the base-line is normally about 1,000 ft.

The precision of the method clearly depends upon the accuracy with which the angle of elevation E can be measured. In practice, a limit to the observational accuracy is set by the fact that the spot of light is never sharply defined, because of the diffuse nature of the cloud surface. A reading to the nearest whole degree is therefore the best that can be expected.



CURVE I: VARIATION OF ELEVATION WITH HEIGHT OF CLOUD; VERTICAL BEAM; BASE-LINE, 1,000 FT. CURVE II: VARIATION OF AZIMUTH WITH HEIGHT OF CLOUD; SEARCHLIGHT AT 76°; BASE-LINE, 1,000 FT.; DIRECTION OF BEAM, 45° FROM DIRECTION OF BASE-LINE

Curve I shows the relationship between E and h for the case L = 1,000 ft. It will be seen that for heights exceeding 4,000 ft. the rate of increase of E with h is very small. The increase of elevation between h = 5,000 ft. and h = 10,000 ft. is, in fact, only 5·6°. As E can only be measured to the nearest degree, cloud heights in this range can therefore only be measured to about the nearest 1,000 ft. The new code for height of cloud adopted by the International Meteorological Committee at Paris in 1946 provides for reporting observations to the nearest 300 ft. in this range. It is necessary, therefore, to consider means of improving upon the accuracy obtainable by the present method.

If the searchlight beam is tilted out of the vertical in a direction transverse to the line of sight, both the azimuth and elevation of the spot of light will vary with the height of the cloud. It is possible, therefore, to make use of the variation of azimuth to determine the height of the cloud. If α is the angle of inclination of the beam to the horizontal plane, β is the angle of orientation of the beam and θ is the

azimuth of the spot of light (β and θ both being measured from the direction of the base line as zero), it is readily shown that

$$h = L \tan \alpha \, . \, \sin \theta \, . \, \operatorname{cosec} (\beta + \theta).$$

It is found that by choosing suitable values for L, α and β, one obtains a relationship between h and θ which is very much more satisfactory for measuring heights exceeding about 2,000 ft. than is possible by using the angle of elevation with a vertical beam. Curve II has been drawn for the case $L = 1{,}000$ ft., $\alpha = 76°$, $\beta = 45°$. It will be seen that for heights above 2,000 ft. Curve II is everywhere substantially steeper than Curve I. In particular, the change of θ between $h = 5{,}000$ ft. and $h = 10{,}000$ ft. is 31°, as compared with a change of 5·6° in E for the same difference of height. The values of α and β used for drawing Curve II are not necessarily the optimum values or those which will be adopted after trials of the method have been carried out.

For heights below about 2,000 ft. the rate of change of elevation with height is very rapid, and is, in fact, rather more rapid with a tilted beam oriented at 45° to the direction of the base line than with a vertical beam. It is concluded, therefore, that the best method of applying the searchlight method is to use the inclined beam system here described, making measurements of elevation for heights up to 2,000 ft., and of azimuth for greater heights.

A fuller discussion of the method will be published elsewhere. I have to thank the Director of the Meteorological Office for giving me permission to publish this preliminary note.

E. G. Bilham

Meteorological Office,
Dunstable, Beds.
March 24.

Electrical Properties of Paint Films on Metals

As part of an investigation on the protective properties of paint films on metals immersed in sea water, a study is being made of the electrical characteristics of such films and their changes with time.

The first approach consisted in following the electrode potential of painted mild steel plates immersed in an artificial sea water, on the lines adopted by earlier workers[1,2], but extending the period of test to cover the various stages of breakdown of the paint film. Plates were abraded, degreased and painted with two coats of an anti-corrosive marine paint, and completely immersed vertically, with provision for an electrical lead shielded from contact with the sea water. The results obtained for several paint systems show that there is a characteristic fall in potential during the first few hours (not well shown on the scale of Fig. 1); after an intervening period of somewhat fluctuating potential, there is a rise to a maximum with a final decline (Curve *B*, Fig. 1). The incidence of this final decline coincides with the time at which rusting begins to spread rapidly (cf. Curve *A*, Fig. 1).

The apparent ohmic resistance and the apparent capacity of the paint film were next investigated, using a Wheatstone bridge with a variable non-inductive resistance in parallel with a variable condenser in one arm of the bridge, in order to balance the resistance and capacity of the cell consisting of two similarly painted plates. Measurements have so far been made only at a frequency of 1,000 cycles per second. The results suggest that the resistance and capacity, especially the latter, are much more sensitive to breakdown of the paint film than is the electrode potential. The onset of rusting is indicated by a sudden large increase in capacity (Fig. 2) and a marked fall in resistance (Fig. 1, Curve *D*). The curves in Fig. 2 (drawn on a larger scale than Fig. 1) show the large capacity changes due to the initial breakdown of paint films consisting respectively of one, two, or three coats.

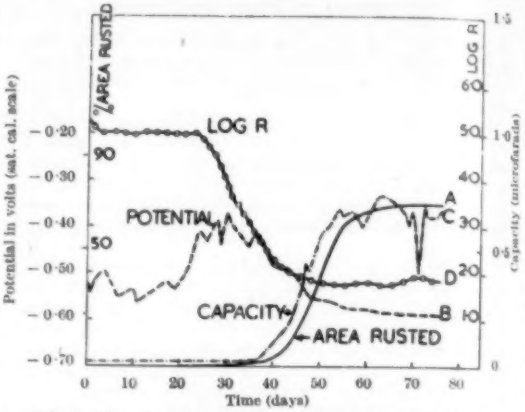


Fig. 1. Relationship between area rusted and changes in electrical properties of paint films on steel

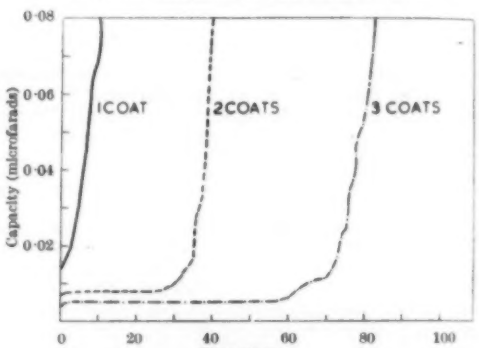


Fig. 2

The general correlation of the changes in all the electrical properties (potential, resistance and capacity) with the gradual spread of rusting over a period of 76 days may be seen from Fig. 1. The figures for rusting represent approximate areas covered by rust; the true corroded area is appreciably less, but this can be estimated only after stopping the test and removing the paint and rust. Curve *A* (Fig. 1) does, however, fairly indicate the rate of spread of rusting, and it can therefore be used as a criterion for interpreting the changes in electrical properties of the paint film.

The values for capacity and resistance given in the graphs are the equivalent parallel capacity and the equivalent parallel resistance, as measured directly. The precise interpretation of these results needs further consideration and will be dealt with in a subsequent communication. It is evident, however, that the conception of the paint film as a 'leaking condenser' must provide the general explanation of the phenomena observed.

It is suggested that the technique should prove valuable as a sensitive means of following quantitatively the breakdown of paint films on metals exposed to aqueous solutions. The method has possible alternative applications to the study of other types of protective coatings and of thin films produced by corrosion inhibitors.

This note is published by permission of the Director of the Chemical Research Laboratory.

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Teddington, Middlesex.
March 4.

[1] Burns, R. M., and Haring, H. E., *Trans. Electrochem. Soc.*, **69**, 169 (1936).
[2] Haring, H. E., and Gibney, R. B., *Trans. Electrochem. Soc.*, **76**, 287 (1939).

Analgesic Activity in Compounds Related to Amidone

AMIDONE (*dl*-2-dimethylamino-4:4-diphenylheptan-5-one) or Hoechst 10820 was made and examined by the I.G. workers at Hoechst during the War. Short preliminary accounts of the properties of this compound have appeared in both the British and American literature, where the activities of some analogous compounds are also described[1,2,3].

As the series is so obviously interesting, we have prepared, in addition to amidone, some of its analogues by condensing diphenylacetonitrile with various aminoalkyl chlorides and treating the resulting basic nitriles with Grignard reagents. Details of some of these compounds are given in Table 1.

In general, the hydrochlorides were very soluble in water, whereas the other salts referred to in Table 1 crystallized readily from aqueous solution.

The analgesic, toxic and respiratory depressant actions have been compared by one of us (R. H. T.) with those of morphine, pethidine and a sample of the lævo form of amidone (*l*-820), obtained from Germany.

Analgesic action was estimated by the method described by Thorp[4], using groups of six rats with varied doses of the compounds compared with doses of 1 or 2 mgm./kgm. of morphine. Respiratory depression was measured in unanæsthetized rabbits after a single dose of the compound under test, the respiratory minute volume being recorded by the method of Gaddum[5]. The doses were adjusted to produce a steady depression of approximately 50 per cent of the normal resting level for at least one hour. The figures for toxicity are the approximate *L.D.*50 values for intravenous injection in mice. The pharmacological results are given in Table 2.

TABLE 2

Compound	Toxicity (mgm./kgm.)	Analgesic activity		Respiratory depressant activity	
		Equiactive doses (mgm./kgm.)	Approximate ratio	Equiactive doses (mgm./kgm.)	Approximate ratio
Morphine	—	2·0	(1·0)	5·0	(1·0)
Pethidine	60·0	15–20	0·15	30·0	0·15
l-820	10·0	1·0	2·0	1·5	3·3
70*C*47	35·0	30–40	0·05	No effect	—
10820	12·5	2·0	1·0	5·0	1·0
72*C*47	25·0	15–20*	0·1	Slight at 10·0	—
97*C*47	20·0	30–40*	0·05	No effect	—
133*C*47	12·0	30–40*	0·05	No effect	—
68*C*47	20·0	4–6	0·4	10·0	0·5
69*C*47	—	60*	0·03	No effect	—
67*C*47	20·0	40*	0·05	No effect	—

* In the case of these compounds, doses smaller than the equiactive dose were used in the test, the response obtained being similar to that for 1·0 mgm./kgm. of morphine.

No figure is given for the toxicity of morphine upon intravenous injection into mice, since these animals are not easily killed by morphine and the *L.D.*50 value (approximately 300 mgm./kgm.) does not correspond to that given by larger animals such as the rabbit.

With compounds having less than 1/10 of the analgesic activity of morphine and relatively high toxicity, the assessment of analgesia is not very reliable, since the doses approach the toxic level. With true analgesic drugs, a graded response is given with doses of 0·1 to 0·25 of the *L.D.*50 toxicity dose for mice.

The results show that, in compounds bearing the 2-dimethylaminopropyl group, analgesic action is optimal in the ethyl ketone 10820, but much less in the shorter- or longer-chain compounds. The radical alterations in the basic side-chain in compounds 68*C*47 and 133*C*47 result in decreased analgesic activity, but again the ethyl ketone is the more potent. Mice injected with compound 68*C*47 show complete narcosis with doses insufficient to cause

TABLE 1

Ref. No.	Name of compound	Structural formula	M.P.'s of base and salts				
			Base	HCl	HBr	HI	HNO_3
70*C*47	2-Dimethylamino-4:4-diphenylhexan-5-one	$CH_3CH(NMe_2)CH_2C(Ph_2)COCH_3$	73	186*	194	181	144
10820	2-Dimethylamino-4:4-diphenylheptan-5-one	$CH_3CH(NMe_2)CH_2C(Ph_2)COC_2H_5$	76	231*	224	198	109
72*C*47	2-Dimethylamino-4:4-diphenyloctan-5-one	$CH_3CH(NMe_2)CH_2C(Ph_2)CO(CH_2)_2CH_3$	Oil	v. deliquescent	88*	156	96
97*C*47	2-Dimethylamino-4:4-diphenylnonan-5-one	$CH_3CH(NMe_2)CH_2C(Ph_2)CO(CH_2)_3CH_3$	Oil	84*	99	96	—
133*C*47	1-Piperidino-3:3-diphenylpentan-4-one	$CH_3CH(CH_2CH_2)_2N.CH_2CH_2C(Ph_2)COCH_3$	Oil	—	162*	158	—
68*C*47	1-Piperidino-3:3-diphenylhexan-4-one	$CH_3CH(CH_2CH_2)_2N.CH_2CH_2C(Ph_2)COC_2H_5$	Oil	—	192*	—	—
69*C*47	1:1-Diphenyl-3-dimethylaminovaleronitrile	$CH_3CH(NMe_2)CH_2C(Ph_2)CN$	91	182*	178	203	169
67*C*47	1:1-Diphenyl-3-piperidinobutyronitrile	$CH_3CH(CH_2CH_2)_2N.CH_2CH_2C(Ph_2)CN$	73	196*	186	152	155

* Compounds tested pharmacologically, and to which the reference numbers apply.

respiratory arrest, whereas the latter symptom is the first to appear after large doses of amidone.

In animal experiments the respiratory depressant activity in these compounds parallels analgesic activity, so that, broadly speaking, in effective compounds a given degree of analgesia is accompanied by a similar degree of respiratory depression.

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Thio-thymine (2-Thio-5-Methyl-Uracil)

Spies *et al.*[1] have reported the value of 5-methyl-uracil (thymine) in the treatment of pernicious anæmia. Jacobson and Williams[2] have suggested the use of splenectomized rabbits for the assessment of anti-anæmic factors, and Bavin and Middleton[3] have shown that thymine causes a reticulocytosis when injected into such splenectomized rabbits. We have used a similar method for the study of the hæmopoietic activity of various thymine derivatives.

Di-hydro-thymine-4-carboxylic acid when injected intramuscularly into splenectomized rabbits in dosages of 100 mgm./kgm. does not cause a reticulocytic response, whereas 2-thio-5-methyl-uracil (in 100 mgm./kgm. dosage) and 2-amino-5-methyl-uracil (100 mgm./kgm.) do (see graph).

The 2-thio-5-methyl-uracil compound (thio-thymine) is particularly interesting in that it contains the —NH.CS.NH— grouping which Astwood[4] has suggested is the common radical in many anti-thyroid compounds. We have found that when this compound is given by mouth to 21-day old female rats (Wistar) in a dosage of 40 mgm./100 gm. daily for ten days and the rats then sacrificed, the thyroids of these rats are grossly enlarged and hyperæmic. Histological examination of the glands revealed colloid loss, increased vascularity, and hyperplasia of the acinar epithelium. A dosage of 20 mgm./100 gm. daily by mouth for ten days did not cause any very marked thyroid changes.

Hence thio-thymine has both anti-thyroid properties and hæmopoietic activity. Moreover, the daily injection of 100 mgm./kgm. intramuscularly for ten days to splenectomized rabbits does not affect the white blood-cell counts of these animals. Again, the intramuscular injection of 20 mgm./kgm. daily (higher dosages caused death of some rabbits from pulmonary œdema) into normal rabbits for ten

●, Thymine, 100 mgm./kgm. intramuscularly
○, Thio-thymine, 200 mgm./kgm. intramuscularly
×, Di-hydro-thymine-4-carboxylic acid, 100 mgm./kgm. intramuscularly
□, Amino-thymine, 100 carboxylic acid, 100 mgm./kgm. intramuscularly

days produced, if anything, a polymorphonuclear leucocytosis (see table). Thio-thymine would seem, therefore, to be free from the depressant action on the bone marrow which has been noted in the use of thiourea[5] and thiouracil[6].

We are indebted to Mr. F. Fowler of Benger's Ltd. for preparing the above compounds.

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Treatment of Myasthenia gravis with Di-isopropylfluorophosphonate

A number of papers have appeared recently dealing with di-isopropylfluorophosphonate, which was prepared by McCombie and Saunders[1] in 1941 and found by Adrian, Feldberg and Kilby[2] to cause a prolonged inhibition of cholinesterase. One of us (J. H. G.) tested its effect on myasthenia gravis in 1943, but had to abandon the work owing to lack of clinical material. This work was continued by the other, and the object of this letter is to report the results.

The drug was injected intramuscularly. In the earlier experiments it was freshly dissolved in water; later, the more stable solution in arachis oil was used. Serum cholinesterase was estimated manometrically using acetylcholine as substrate, and the strength of the muscles controlling the hand was measured with a dynamometer. Neostigmine (prostigmine) had its usual dramatic effects on all these patients. General weakness, ptosis, diplopia and dysphagia disappeared

Type of animal	Dosage of thio-thymine (mgm./kgm.)	White blood cell count in thousands on days										
		1	2	3	4	5	8	9	10	11	12	15
Normal rabbit	20	8·4	6·6	10·6	16·8	16·0	15·5	17·8	19·8	19·8	15·2	21·4
Splenectomized rabbit	100	10·8	12·0	9·6	8·1	7·7	11·3	12·9	13·0	12·7	8·7	10·3

The above figures are the average counts from three rabbits. Injections were given daily from day 3 to day 14.

within about half an hour and returned after two to three hours. The serum cholinesterase activity fell and the readings of the dynamometer rose; these changes occurred at about the same time as the clinical improvement. The injection of di-isopropylfluorophosphonate (0·1–10 mgm.) caused no obvious immediate clinical improvement, but the serum cholinesterase activity fell and the dynamometer readings rose within half an hour, and these changes lasted longer than the corresponding changes after neostigmine.

The absence of clinical improvement in spite of a marked fall in serum cholinesterase in these experiments was interesting but disappointing. It was, however, noticed that dynamometer readings taken at 10 a.m. showed a small rise lasting a number of days after injections of the drug. Experiments were therefore undertaken to test the effect of a daily dose. In three patients, 0·5–2 mgm. was injected once daily for periods up to three months. Neostigmine was also given in the early stages of this treatment. In two cases there was marked clinical improvement after one to two weeks of this treatment, and the daily requirements of neostigmine fell. The dynamometer readings taken 24 hours after the injections showed a marked rise, and the serum cholinesterase was reduced by 86–90 per cent. These patients were eventually discharged from hospital and continued to give themselves 0·5 mgm. per day, and have reported satisfactory progress so far. Atropine was given to counteract the muscarine actions of the di-isopropylfluorophosphonate; but in spite of this, all three patients complained of tightness of the chest, and in one case treatment was abandoned because of this effect.

These results are in general agreement with those of Comroe *et al.*[3].

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Effect of Calciferol and of Penicillin on Experimental Tuberculosis of Guinea Pigs

Among the many points touched upon in recent literature of tuberculosis are: (1) the favourable results in the treatment of lupus, and possibly other forms of surgical tuberculosis, with calciferol[1–3]; (2) the conflicting results reported by various workers[4–6] as to the effect of penicillin. In the course of an extensive experimental study of the chemotherapy of tuberculosis, we have made observations bearing upon these questions which it is thought are of sufficient interest to report briefly.

500-gm. guinea pigs were infected with 0·001 mgm. of human tubercle bacilli (strain *H.*418) intramuscularly, and after four weeks, when all pigs were tuberculin positive, various treatments were commenced and continued for ten weeks. Survivors of all treated groups and of untreated controls were killed and assessed for infection by the method of Sher and Kloeck[7]. Individual and average assessments are given in the accompanying table; survival times were also noted. Streptomycin was taken as an active drug control, but only five animals were killed when this experiment terminated, as previous work had shown that the amount of drug given was enough to suppress the disease during the period of treatment (ten weeks).

Details of drug dosage are as follows:

Penicillin: 500 u. / guinea pig / day subcutaneously in saline given in two doses of 200 and 300 units a.m. and p.m.

Calciferol: 2,000 u. / guinea pig / day in arachis oil given with the food.

Streptomycin: 10,000 u. / guinea pig / day subcutaneously in saline given in two doses of 4,000 and 6,000 units a.m. and p.m.

Group	Deaths	T.B. assessments	Average
Untreated (14)	5/14	71*, 74, 53, 85*, 51 88, 85, 49, 88*, 81* 65, 81,* 84, 85	74·3
Penicillin (11)	8/11	75*, 73*, 71*, 73, 83* 61, 86, 88, 82*, 65* 79*	75·5
Calciferol (12)	5/12	88*, 78*, 69, 98*, 66 68, 76*, 86*, 62, 79 71, 71	76·0
Streptomycin (50)	0/50	5 killed at random 4, 2, 4, 2, 2	2·8

* Asterisk denotes death of animal

It is obvious from the results that there is no difference between the extent of tuberculosis of penicillin-treated, calciferol-treated and control groups.

There was no evidence of toxicity or abnormal calcification in the animal treated with calciferol, nor in a group of normal guinea pigs which received 25,000 units of calciferol a day for ten weeks. These doses roughly correspond to those used in the treatment of lupus vulgaris in man.

I wish to thank Sir Jack Drummond, who suggested the work on calciferol, Mr. C. E. Coulthard, for his interest in these investigations, and Mr. B. H. Chantrill, for help with the *in vivo* work.

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Fibrinolysis in the Animal Organism

It is now known that the action of the fibrinolytic substance produced by certain streptococci is due to its properties as an activator for the transformation of a proenzyme present in blood serum and plasma into a proteolytic enzyme acting on the fibrin. This activation can also be carried out by treatment with chloroform (for references see Christensen[1] and Kaplan[2]). Considerable confusion concerning the nomenclature for the substances interacting in the fibrinolysis exists; but it seems most logical to use the proposal of Loomis, George and Ryder[3]. According to this, the name 'fibrinolysin' is used for the active fibrinolytic enzyme, while the inactive pre-

cursor is termed 'profibrinolysin'. The activating principle produced by streptococci, and previously termed fibrinolysin, is called 'streptokinase'. This nomenclature expresses thus the similarity between the system in question and certain other enzyme systems, for example, the formation of trypsin and thrombin.

We have found that profibrinolysin can be transformed into fibrinolysin by an activator contained in animal tissue cells. The occurrence in the animal organism of a process of this type was suggested by Fischer[4].

Ox fibrinogen prepared from Bordet plasma was used. The preparations of ox thrombin contained 10–13 of our thrombin units per mgm.[5,6] (obtained from Løvens Kemiske Fabrik, Copenhagen). All experiments were performed aseptically with sterile solutions.

In a fibrin clot prepared from these solutions, tissue slices from different organs from mammals (ox, pig, rabbit and rat) produced fibrinolysis, the degree of which depended upon the nature of the organ and the species of the animal used. Tissues from chicken and hen were inactive, a fact which is of considerable interest in view of the species specificity disclosed in the proteolytic activity of malignant tissue cells[4]. Streptokinase also was inactive when tested on ox fibrinogen.

Fibrinogen solutions from which the fibrinogen was removed, that is, by heating to 56° for 5 min. or by clotting with thrombin, contained after incubation for 24 hr. with washed tissue fragments at 37° a powerful fibrinolytic enzyme. This indicates the presence of a profibrinolysin in the original fibrinogen solution.

The ability of the tissue to activate profibrinolysin was retained undiminished after several weeks in water containing toluene and chloroform as preservative, and was not dependent on the metabolism of the living cell. It was not found possible to extract the activator from the tissues, but washed suspensions were very active. The activation of fibrinolysin is thus a general property of normal tissue cells. In continuation of the nomenclature mentioned above, we propose to call this activating principle 'fibrinokinase'. The name should really be 'cyto-fibrinokinase', and the activating principle from streptococci should be called 'strepto-fibrinokinase'; fibrinokinase thus being a term for a group of different chemical compounds exhibiting the common property of being able to activate profibrinolysin to form fibrinolysin.

It may be of value to point out the general nature of the principle for producing active substances in the living organism as expressed in the reactions mentioned. Together with the renin-hypertensin system, they represent a type of reactions, in which a tissue component (thrombokinase, renin, fibrinokinase) acts upon a protein circulating in the blood stream (prothrombin, hypertensinogen, profibrinolysin) in order to produce an active substance of high potency (thrombin, hypertensin, fibrinolysin). In addition to the specific inactivating substances present in the blood (antithrombin, hypertensinase, antifibrinolysin), this mechanism serves the organism as a means of regulating the amount of certain substances the formation of which might be dangerous.

A detailed study of the fibrinokinase–fibrinolysin system is being carried out by one of us (P. M. P.), and the results will be published in due course.

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Oriented Movement of Blue-Green Algæ on a Stretched Gel

TROPISTIC and tactic responses to stresses in an elastic substrate have been described for several kinds of biological material. The true bacterium *Kurthia zopfii*, when grown in gelatin subjected to mechanical tension, reflects precisely in its pattern of growth the pattern of stresses in the substrate[1–3]; a similar response is shown by nerve fibres cultivated on stretched coagulated plasma[4]. Jacobsen[1] proposed the name 'elasticotropism' for this type of behaviour. A few years ago, the corresponding tactic response was demonstrated in myxobacteria on stretched agar gels[5]. The effect of elasticotaxis in these organisms is particularly striking through its secondary influence on the fruiting process; the rigidly oriented movement of the vegetative cells causes marked abnormalities in the shape and distributional pattern of the fruiting bodies.

Recently I have observed elasticotactic behaviour in two strains of blue-green Algæ belonging to the family Nostocaceæ, received from Dr. T. Gibson, by whom they were isolated in pure culture. It is easy to follow the movement of these organisms on agar, since motile trichomes leave visible 'tracks' on

Fig. 1 Fig. 2 Fig. 3

Fig. 1. TYPICAL ARRANGEMENT OF TRICHOMES AND TRACKS ON UNSTRETCHED AGAR
Fig. 2. ORIENTATION OF TRICHOMES ON STRETCHED AGAR. THE ARROW INDICATES THE DIRECTION OF STRESS
Fig. 3. ANOTHER EXAMPLE OF ORIENTATION ON STRETCHED AGAR. THE LINEARITY AND PARALLELISM OF THE TRACKS IS PARTICULARLY CLEAR. THE ARROW INDICATES THE DIRECTION OF STRESS
(Tracks appear as faint light-coloured markings not easily seen in the reproductions.)

the surface of the medium over which they have travelled. When an agar plate is heavily inoculated in one spot and exposed to even illumination, the trichomes creep out evenly from all sides of the inoculum, for the most part following curved paths. Microscopic examination of the agar surface surrounding the inoculum on a plate several days old shows the presence of a large number of randomly oriented trichomes, the areas between them being covered with a network of curved tracks (Fig. 1). However, if the agar is initially subjected to tension (by laying a strip over a glass rod, for example), a markedly different pattern of movement develops. The trichomes move only in straight lines parallel to the applied stress, all migration from the inoculum at right-angles to the stress being prevented. On microscopic examination the trichomes are found to be rigidly oriented with their long axes parallel to the stress, and the tracks appear as a series of beautifully parallel straight lines (Figs. 2 and 3). As the organisms reach areas of decreased tension a certain amount of disorientation makes its appearance, and those trichomes which succeed in reaching a completely unstressed region of the agar regain their liberty of movement, reverting to the normal random orientation and following curved paths. When trichomes pass from an area of tension to one of compression, their orientation changes by 90°. The elasticotactic behaviour of blue-green Algæ is similar in all respects to that of myxobacteria, but the former organisms provide more favourable material for study of the phenomenon, because of their relatively much greater size and their formation of tracks on the substrate.

Since blue-green Algæ and myxobacteria have long been considered to possess similar mechanisms of locomotion, the identity of elasticotactic response in the two groups is not a matter for surprise. It would be interesting to know whether micro-organisms the movement of which on solid surfaces is effected by radically different mechanisms (for example, diatoms and amœboid protists) also respond to this stimulus.

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Genetics of Red Body Colour in *Armadillidium vulgare*

Previous work[1,2] and also many unpublished results have shown that in the woodlouse *Armadillidium vulgare* Latr. red body colour and a colour pattern called type *D* behave as simple autosomal dominants to the common black and grey types (the only complication being that in adult animals type *D* is sex-limited to the female sex). Collinge[3,4,5], however, has reported results which do not agree with mine in that he fails to find any segregations. I was inclined to believe that Collinge's results were due to his scoring animals before they were really old enough for the different colour types to be distinguished; for he had stated[6] that, when he examined some young from the variety *rufobrunneus* (red) at just over three weeks old, no trace of red or brown coloration was apparent, and that, if he had not known their history, he would have identified them as young specimens of the variety *plumbeus* (grey-black). While it must be emphasized that in the majority of cases red colour does behave as a simple dominant, and that one does usually obtain good 1 : 1 and 3 : 1 segregations, I have recently obtained some results which confirm Collinge's observations.

The first unexpected result was brood 223 from the red, type *D* female *GN*, which was collected pregnant from Four Went Ways. This brood consisted of 95 black animals and 0 reds. This, of course, can be explained if we assume that there is a recessive gene for red as well as a dominant. Vandel[7] has, in fact, found recessive red types in *Armadillidium vulgare*. Segregation for type *D* in brood 223 was normal, the 92 females consisting of 48 type *B* (the common female colour pattern) and 44 Type *D*.

The second set of unexpected results started with the red, type *B* female *AU*, also obtained already pregnant from Four Went Ways. Brood 185 from this female consisted of 15 red : 35 black. The animals from this brood were numbered *AUA* to *AUF*, and their breeding behaviour is shown in the table below:

Female	Parents Male	Brood number	Segregation Red	Segregation Black
AUA (red)	Brood 185 red male	212	22	0
AUB (red)	Brood 185 red male	213	30	0
AUB (red)	None since brood 213	240	51	0
AUC (red)	Brood 185 red male	214	18	0
AUC (red)	*CRA* (black)	237	0	3
AUD (red)	Brood 185 red male	215	36	0
AUD (red)	*AYA* (black)	245	0	33
AUE (red)	*FM* (black)	238	0	56
CU (red)	Pregnant when collected	187	15	19
CU (red)	None since brood 187	230	33	52
CU (red)	*AUF* (red)	239	53	0

It will be noticed first that red females from brood 185, mated with their own brothers, produce broods consisting of red animals only, and secondly that the same females when mated with unrelated black males produce broods consisting of black animals only. Both these facts would fit the hypothesis that the red colour of female *AU* and her offspring was due to a recessive gene. This explanation, however, probably breaks down when we consider brood 239. Female *CU* was obtained from the Cambridge University Farm, and all other red animals from this locality have always been dominant reds. The segregations in broods 187 and 230 are thus probably due to female *CU* being heterozygous for dominant red and to her having mated with a common black male. If this is so, then male *AUF* appears to be homozygous for dominant red and not for recessive red.

The true explanation of the above results is not yet known, and it is obvious that one easy test, namely, to inbreed black animals from broods 185, 238 and 245, remains to be done. On the other hand, the results may not be explainable on normal Mendelian lines, since it is already known[1,2,8] that sex ratios in *Armadillidium* and other woodlice are peculiar. It is also interesting to note that the Four Went Ways population is peculiar in containing quite a number of intersexes, including the one described by Collinge[9].

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AMERICAN AWARDS TO BRITISH MEN OF SCIENCE

THE Medal for Merit, which has its origin in an order by President Washington, is the highest award made by the Government of the United States to a civilian. We print below the names of British men of science recently awarded the Medal, with the accompanying citations:

SIR EDWARD APPLETON, for exceptionally meritorious conduct in the performance of outstanding services to the United Nations. Sir Edward, as secretary of the Department of Scientific and Industrial Research and chairman of the British National Committee for Radio Telegraphy, organised and supported scientific workers, prosecuting many of the important scientific projects which resulted in Allied supremacy. He was outstanding in the effectiveness of his work for co-operation between British and American scientists, and was responsible for important phases of the early research leading to the development in England and the United States of modern radar.

PROF. P. M. S. BLACKETT, for exceptionally meritorious conduct in the performance of outstanding services to the United Nations. Prof. Blackett, a British pioneer in the field of operational research, not only played a decisive role in the scientific war activities of his own country, but his inspiring leadership stimulated developments in the United States similar to those initiated by him in Great Britain. His brilliant analysis and interpretation of operation data was a major factor leading to the Allied success in the anti-submarine campaign. The value of his work to the United States was outstanding, and his advice and counsel to us were invaluable contributions to the war effort.

DR. ROBERT COCKBURN, for exceptionally meritorious conduct in the performance of outstanding services to the United Nations. Dr. Cockburn, as head of the Counter-measures Group of the Telecommunications Research Establishment in the Ministry of Aircraft Production, was instrumental in devising new electronic techniques to counter the enemy's use of fire control methods, navigation aids and bombing devices. He was one who early appreciated the high importance of electronic intelligence, and devised equipment and analytical methods to seek out this intelligence. He exerted himself to provide for co-operation between British and American scientists. In the field of radio and radar counter-measures, Dr. Cockburn was the British scientist who above all others had the most comprehensive grasp of the scientific and operational problems involved.

MR. A. P. ROWE, for exceptionally meritorious conduct in the performance of outstanding services to the United Nations. Mr. Rowe, as head of the great Telecommunications Research Laboratory of the Ministry of Aircraft Production throughout the War, and himself a stimulating and energetic leader of men, exercised a dominant role in the development of radar and counter-measures in the United Kingdom. When American scientists working in these fields proposed to establish advanced laboratories in England, he co-operated enthusiastically, opening his own establishment for their equal use. The inter-Allied discussions at the Telecommunications Research Establishment were famous for their frankness and stimulation. Co-operation was strenuously advocated by him; and in the development and employment of electronics in warfare Mr. Rowe made important contribution.

SIR REGINALD STRADLING, for exceptionally meritorious conduct in the performance of outstanding services to the United Nations. Sir Reginald, as chief adviser on research and experiments to the Ministry of Home Security from 1940 throughout the War, conceived and directed the far-flung British experiments and observations of the effects of bombs. His revolutionary work led to data of vital importance in the air war with Germany. He pioneered in the measurement of blast, which materially affected the entire study of explosive effects culminating with the atomic bomb. He freely made available to the United States the information and resources at his command. He welcomed and trained many young Americans at his Princes Risborough Station in the techniques he had discovered. Sir Reginald's contributions were of invaluable aid to the Allies in time of great peril.

SIR GEOFFREY TAYLOR, for exceptionally meritorious conduct in the performance of outstanding services to the United Nations. Sir Geoffrey's researches during the War exercised a notable influence on American investigations. His inquiring intellect penetrated into the depths and brought up certain knowledge. He established fundamental truths in fluid dynamics and gas dynamics. He gave inspiration and direction to research in shock-wave propagation, detonation and underwater explosion. His work will continue to influence scientific development, and his contributions were of inestimable value to the war effort.

SIR HENRY TIZARD, for exceptionally meritorious conduct in the performance of outstanding services to the United Nations. Sir Henry, as leader of the British Technical Mission to the United States in 1940, initiated Anglo-American scientific relations, concluding arrangements for the interchange of information relating to the development of devices for warfare. Later, as scientific advisor to the Air Ministry and member of the Council of the Minister of Aircraft Production, he was a central figure in assuring that research and development as well as operational information of high value in the solution of American problems of aerial warfare, be made available to the United States. Of brilliant mind, gifted with wide imagination, Sir Henry's contribution to the scientific effort of the War was unique.

SIR ROBERT WATSON-WATT, for exceptionally meritorious conduct in the performance of outstanding services to the United Nations. An outstanding authority on radar, Sir Robert's years of work, in a field little frequented, largely formed the basis of the extraordinary early success of British radar when the onset of the War engulfed England in a wave of bombing. His keen technical foresight and ability to organise, with his understanding of human nature, were capitalized in the 'Battle for Britain'. The success attained in the military employment of these new scientific devices and methods inspired and stimulated the great radar programme in the United States. He collaborated in every way with American research groups. In the development and effective combat employment of superior types of radar, radar counter-measures and communications equipment, Sir Robert's services were of enormous value.

LINEN INDUSTRY RESEARCH ASSOCIATION

ANNUAL REPORT

THE report of the Council of the Linen Industry Research Association (from the Association, Lisburn, Northern Ireland) for the year ended September 30, 1946, records that the whole of the linen industry and trade in Northern Ireland are now members of the Association, which has thus become fully representative on a purely voluntary basis. The rate of subscription paid by each individual member has also substantially increased, and the Association has qualified for the maximum possible grants from the Department of Scientific and Industrial Research and the Government of Northern Ireland. Some additions have already been made to the staff, but in building up a strong, well-qualified body of workers, the Association is in competition with other demands for the limited number of new science graduates available. A good proportion of the Association's staff is trained by the Association, and during the year the value of the Association's scholarship open to first-class honours graduates in science of the Queen's University, Belfast, was considerably increased. Plans have been considered for a new technological building, but this is not expected to be completed for some time.

In pursuance of the new arrangements for keeping members in touch with the latest developments at the Institute, heads of departments are now visiting the individual Scottish members of their section twice yearly. The director and head of the Chemistry Department were members of the linen industry investigating mission in Germany during June–July 1946, and the director of research is also a member of the Flax Committee and chairman of its Flax Utilization Sub-Committee. Referring to the large reduction in acreage under flax in Northern Ireland in 1945 and 1946, the Council in its report emphasizes the urgency of research in making the growing of flax more economical in view of this increased dependence on foreign supplies of flax.

Research work noted in the report includes the statistical analysis of records of soil conditions and yields of crops, seed and fibre during 1941–44; studies to determine the effect of time of pulling on retting behaviour and on yield and quality of fibre, and spinning tests of lots of flax from the 1944 crops. An attempt has been made to devise a more objective test than the usual pull-off test for determining the end-point of retting, and an investigation of the causes of low yields with turbine scutching machines has shown that improved yields may be obtained by suitable pre-breaking and proper positioning of the grip by the feed on the conveyor belt and by modification of the beaters. The fifty per cent average loss of efficiency of clean fibre extraction is attributed to factors causing breakage of the fibre strands or straw. Data obtained in an investigation of the relation between fibre qualities and yarn quality have already thrown light on important technical problems.

The hot-air drying of flax yarn in hank form and the levelness of rayon staple yarns spun on flax machinery have also been investigated. Weaving research has centred on the performance of warp stop motions on looms, modifications to looms and methods of weaving to reduce warp breaks and improve cloth quality, and efficiency surveys in factories.

Work on dyeing and bleaching has aimed at increasing efficiency and improving quality, and particularly at securing the maximum fastness to laundering. In finishing studies, particular attention has been directed to crease-resistant treatments, and work on the proofing of canvas fabrics against attack by various agencies has continued.

ANTIBIOTIC ACTION OF AN EXTRACT OF *GALLERIA MELLONELLA**

By PROF. H. R. OLIVIER

LARVÆ of *Galleria mellonella* are selected in their adult state a little before they begin to form their cocoons. Ground up and the chitinous cuticle filtered off, they are extracted with acetone. This extract is washed three times with $N/10$ sodium hydroxide. The three liquors thus obtained are freed of acetone, neutralized to *p*H 7·5, and each is concentrated so that 1 c.c. corresponds to 1 gm. of larval bodies.

Tubes containing 10 c.c. of glycerinated veal broth are then inoculated with 0·1 c.c. of a four-day culture of the homogeneous tubercle bacillus of Arloing and Courmont, and to these are added increasing quantities of the extracts of *Galleria mellonella*. The accompanying table shows one of our experiments, the dosages I, II and III representing the successive extractions of the original acetone extract.

	Date	4th	6th	8th	10th	12th	Lysis experiment
	Control	++	++	++	++	++	
I	0·05 c.c.	+−	++	++	++	++	Bacilli of normal aspect
	0·1 c.c.	−	+−	+	+	+	
	0·5 c.c.	−	−	+	+	+	
	1·0 c.c.	−	−	−	−	−	
II	0·01 c.c.	+	++	++	++	++	Bacilli of normal aspect
	0·1 c.c.	+−	+	+	++	++	
	0·5 c.c.	+−	+−	+−	+−	+−	
III	0·01 c.c.	Subtilis					Bacilli clumped, badly staining, and of ill-defined contour
	0·1 c.c.	−	−	+ Subtilis	+	+	
	0·5 c.c.	−	−				

In all our experiments the extracts have begun to show activity at a dosage of 0·1 c.c. If, by analogy with our experiments with 'Endosubtilysine', this is taken as a unit of activity, our extract has an action against the bacillus of Arloing and Courmont corresponding to 30 units per gm. of larval bodies.

We then added to 2 c.c. of a homogeneous culture of the bacillus of Arloing and Courmont, five days old, 1 c.c. of each of the three alkaline liquors I, II and III. After forty-eight hours incubation the mixtures were centrifuged and the deposit stained by the Ziehl method and examined. The bacilli were greatly altered by liquor III, staining badly, and being thickened and ill-defined in contour.

Conclusions. The larvæ of *Galleria mellonella* contain a substance extractable with acetone and possessing an antibiotic action against the homogeneous tubercle bacillus of Arloing and Courmont. In high concentration the extract appears to produce lysis in the same organism.

* Translated by Dr. James Marshall.

FORTHCOMING EVENTS

*(Meetings marked with an asterisk * are open to the public)*

Tuesday, May 20

EUGENICS SOCIETY (at the Royal Society, Burlington House, Piccadilly, London, W.1), at 5.30 p.m.—Dr. H. J. Eysenck: "Measurement of Socially Valuable Qualities".*

UNIVERSITY COLLEGE (at Gower Street, London, W.C.1), at 5.30 p.m.—Dr. E. J. Holmyard: "History of Chemistry in Islam" (another lecture on May 23).*

Wednesday, May 21

ROYAL METEOROLOGICAL SOCIETY (at 49 Cromwell Road, South Kensington, London, S.W.7), at 5 p.m.—Prof. O. G. Sutton: "The Problem of Diffusion in the Lower Atmosphere"; Mr. W. G. V. Balchin: "A Microclimatological Investigation of Bath and the Surrounding District".

ROYAL SOCIETY OF MEDICINE, ENDOCRINOLOGY SECTION (at 1 Wimpole Street, London, W.1), at 5 p.m.—Discussion on "New Aspects of Insulin Action" (to be opened by Prof. F. G. Young (biochemical aspects), and Dr. R. D. Lawrence (clinical aspects)).

ROYAL MICROSCOPICAL SOCIETY (in the Hastings Hall, B.M.A. House, Tavistock Square, London, W.C.1), at 5.30 p.m.—Discussion on the Programme of the Scientific Film Panel, and an Exhibition of Films.

INSTITUTE OF METALS (at the Institution of Civil Engineers, Great George Street, London, S.W.1), at 6 p.m.—Sir Wallace Akers: "Metallurgical Problems involved in the Generation of Useful Power from Atomic Energy" (Thirty-seventh May Lecture).

Thursday, May 22

CHADWICK PUBLIC LECTURE (at the Town Hall, Cheltenham), at 3 p.m.—Sir Arthur MacNalty, K.C.B.: "Advances in Preventive Medicine during the War of 1939–45".*

LONDON MATHEMATICAL SOCIETY (at the Royal Astronomical Society, Burlington House, Piccadilly, London, W.1), at 5 p.m.—Prof. H. Jeffreys, F.R.S.: "Probability".

MINERALOGICAL SOCIETY (at the Geological Society of London, Burlington House, Piccadilly, London, W.1), at 5 p.m.—Prof. S. Tolansky: "An Interferometric Survey of Mica".*

ROYAL STATISTICAL SOCIETY (at the London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1), at 5.15 p.m.—Mr. R. M. Shone: "The Iron and Steel Development Plan—some Statistical Considerations".

Friday, May 23

SOCIETY OF CHEMICAL INDUSTRY, FOOD GROUP (joint meeting with the BIRMINGHAM AND MIDLAND SECTION, at the Birmingham Chamber of Commerce, New Street, Birmingham), at 2.30 p.m.—Discussion on "Trade Wastes" (Dr. B. A. Southgate: "Effects of Polluting Discharges"; Dr. S. H. Jenkins: "Principles of Trade Waste Treatment").

ROYAL ASTRONOMICAL SOCIETY (at Burlington House, Piccadilly, London, W.1), at 4.30 p.m.—Discussion of Geophysical Papers.

Sunday, May 25

SOCIETY FOR VISITING SCIENTISTS, THE ASSOCIATION OF SCIENTIFIC WORKERS and THE WORLD FEDERATION OF SCIENTIFIC WORKERS (at the Beaver Hall, Garlick Hill, London, E.C.4), at 7.45 p.m.—Meeting in Memory of Paul Langevin.*

APPOINTMENTS VACANT

APPLICATIONS are invited for the following appointments on or before the dates mentioned:

LECTURER IN PHYSICAL CHEMISTRY, a LECTURER IN PHARMACEUTICAL CHEMISTRY, a LECTURER IN METALLURGY, a LECTURER IN PHYSICS, and a LECTURER IN BIOLOGY—The Registrar, College of Technology, The Newarke, Leicester (May 24).

SCIENTIFIC ASSISTANTS (women) IN THE SOIL CHEMISTRY DEPARTMENT, East African Agricultural Research Station, Amani, Tanganyika—The Director of Recruitment (Colonial Service), Colonial Office, 15 Victoria Street, London, S.W.1 (May 24).

LECTURER IN CHEMISTRY AND METALLURGY—The Registrar, Technical College, Sunderland (May 24).

LECTURER IN MATHEMATICS—The Clerk to the Governors, Woolwich Polytechnic, Woolwich, London, S.E.18 (May 24).

SENIOR RESEARCH CHEMIST—The Director, Institute for Industrial Research and Standards, 45 St. Stephen's Green, Dublin (May 24).

LECTURER IN ORGANIC CHEMISTRY at the Coventry Technical College—The Director of Education, Council House, Coventry (May 24).

RESEARCH BIOLOGIST to work in a team studying Plankton Ecology in relation to the Fisheries—The Registrar, University College, Hull (May 24).

EDITORIAL OFFICER—The Hon. Secretary, Society of Dyers and Colourists, 32–34 Piccadilly, Bradford, endorsed 'Editorial Officer' (May 24).

SENIOR ASSISTANT IN THE DEPARTMENT OF METALLURGY—The Principal, Central Technical College, Suffolk Street, Birmingham 1 (May 24).

SENIOR ASSISTANT LECTURER IN MECHANICAL ENGINEERING up to Higher National Certificate standard—The Principal, Handsworth Technical College, Golds Hill Road, Handsworth, Birmingham 21 (May 24).

SENIOR ASSISTANT FOR ELECTRICAL ENGINEERING, and a TEACHER IN MECHANICAL ENGINEERING subjects—The Principal, Municipal Technical College, Hopwood Lane, Halifax (May 24).

LECTURER IN MECHANICAL ENGINEERING subjects in the Ipswich School of Technology—The Chief Education Officer, Education Department, 17 Tower Street, Ipswich (May 24).

HEAD OF THE DEPARTMENT OF PHYSICS, MATHEMATICS AND NAVIGATION, Plymouth Technical College—The Director of Education, Education Office, Coburg Street, Plymouth (May 24).

ASSISTANT LECTURER (Grade III) IN THE DEPARTMENT OF PHILOSOPHY—The Registrar, The University, Liverpool (May 30).

SCIENCE EDITOR—The Director, Appointments Department, British Council, 3 Hanover Street, London, W.1 (May 30).

CHIEF STATISTICAL OFFICER to the Ministry of National Insurance—The Secretary, Civil Service Commission, 6 Burlington Gardens, London, W.1, quoting No. 1877 (May 31).

RESEARCH SCHOLARSHIP IN VERTEBRATE ZOOLOGY—The Registrar, The University, Bristol 8 (June 1).

CHEMISTS (men and women) as ASSISTANT EXPERIMENTAL OFFICERS at the Ministry of Supply Atomic Energy Centre near Preston—The Ministry of Labour and National Service, Technical and Scientific Register, Room 171, York House, Kingsway, London, W.C.2, quoting F.339/47A (June 4).

CHEMISTS (women) IN THE SCIENTIFIC AND EXPERIMENTAL OFFICER CLASSES at the Ministry of Supply Atomic Energy Centre near Preston—The Ministry of Labour and National Service, Technical and Scientific Register, Room 171, York House, Kingsway, London, W.C.2, quoting F.330/47A (June 4).

PROFESSOR OF ELECTRICAL TECHNOLOGY at the Indian Institute of Science, Bangalore—The High Commissioner for India, General Department, India House, Aldwych, London, W.C.2 (June 7).

SENIOR ORGANIC CHEMIST IN THE BIOCHEMISTRY SECTION for work on the organic constituents of fruit-bearing plants—The Secretary, East Malling Research Station, East Malling, Kent (June 7).

ANIMAL HUSBANDRY OFFICERS (2) IN THE DEPARTMENT OF AGRICULTURE AND LANDS, Southern Rhodesia—The Secretary, Office of the High Commissioner for Southern Rhodesia, Rhodesia House, 429 Strand, London, W.C.2 (June 7).

RESEARCH OFFICER, TIMBER PRESERVATION SECTION, Division of Forest Products, Melbourne—The Secretary, Australian Scientific Research Liaison Office, Australia House, Strand, London, W.C.2, quoting No. 1187 (June 9).

LECTURER IN THE DEPARTMENT OF SOCIAL STUDIES, and an ASSISTANT TUTOR IN PRACTICAL SOCIAL WORK—The Registrar, The University, Leeds 2 (June 9).

READERSHIP IN APPLIED MECHANICS at the Imperial College of Science and Technology—The Academic Registrar, University of London, Senate House, London, W.C.1 (June 12).

PRINCIPAL SCIENTIFIC OFFICER AT THE ARMAMENT DESIGN DEPARTMENT of the Ministry of Supply, Fort Halstead, Kent—The Secretary, Civil Service Commission, 6 Burlington Gardens, London, W.1, quoting No. 1871 (June 14).

PRINCIPAL SCIENTIFIC OFFICER AT THE TELECOMMUNICATIONS RESEARCH ESTABLISHMENT of the Ministry of Supply, Malvern, Worcs.—The Secretary, Civil Service Commission, 6 Burlington Gardens London, W.1, quoting No. 1870 (June 14).

PROFESSOR OF MINING—The Registrar, University College, Nottingham.

METEOROLOGICAL ASSISTANTS (both sexes)—The Under-Secretary of State, Air Ministry (S.2b), Cornwall House, Stamford Street, London, S.E.1.

LECTURERS (3) FOR MECHANICAL ENGINEERING subjects to the Higher National Certificate and University Degree standard, and a LECTURER IN PHYSICS to London University special degree standard—The Clerk to the Governors, South-West Essex Technical College and School of Art, Forest Road, Walthamstow, London, E.17.

TECHNICIAN in charge of the new Clinical Photographic Department—G. Hurford, Queen Elizabeth Hospital, Birmingham 15.

LABORATORY TECHNICIAN—The Medical Superintendent, Notts. County Mental Hospital, Radcliffe-on-Trent, Notts.

INSTRUMENT RESEARCH OFFICER, and an EXPERIMENTAL OFFICER for testing dairy plant and equipment—The Secretary, National Institute for Research in Dairying, Shinfield, Reading.

SENIOR LABORATORY STEWARD FOR SCIENCE DEPARTMENT—The Principal, County Technical College, Essex Road, Dartford.

LECTURER AND DEMONSTRATOR IN AGRICULTURAL CHEMISTRY—The Principal, Harper Adams Agricultural College, Newport, Shropshire.

LECTURER IN CHEMISTRY—The Clerk to the Governors of the Technical College, Education Offices, North Street, Wolverhampton.

PHYSICAL CHEMIST for work in connexion with Steelmaking, Slags and Refractories—The Personnel Officer, British Iron and Steel Research Association, 11 Park Lane, London, W.1, quoting 'Refractories Section'.

PHYSICIST to work mainly on the physical properties of leather, rubber, plastics and other shoe materials, and a STATISTICAL MATHEMATICIAN to work on foot measurement surveys of the population—The Director, British Boot, Shoe, and Allied Trades Research Association, Satra House, Rockingham Road, Kettering, Northants.

LECTURER or ASSISTANT PROFESSOR IN THE DEPARTMENT OF BIOCHEMISTRY—The Professor of Biochemistry, Faculty of Medicine, University of Manitoba, Winnipeg, Canada.

LABORATORY STEWARD (Grade IIA) FOR ORGANIC CHEMISTRY—The Registrar, The University, Leeds 2.

SENIOR ASSISTANT IN THE DEPARTMENT OF CIVIL AND MECHANICAL ENGINEERING to teach Advanced Theory and Design of Structures and Surveying, a SENIOR ASSISTANT IN THE DEPARTMENT OF CHEMISTRY to teach Physical Chemistry to Final B.Sc. (special) Degree standard, and a LECTURER IN CHEMISTRY to teach Organic Chemistry to Final B.Sc. (special) Degree—The Principal, Technical College, Queen Street South, Huddersfield.

SENIOR ASSISTANT IN MECHANICAL OR CIVIL ENGINEERING, a LECTURER IN MECHANICAL ENGINEERING subjects, a LECTURER IN ELECTRICAL ENGINEERING subjects, and a SENIOR LABORATORY STEWARD IN THE CHEMISTRY AND BIOLOGY DEPARTMENT—The Registrar, Municipal College, Portsmouth.

LECTURER (graduate) IN CHEMISTRY in the St. Helens Municipal Technical College—The Director of Education, Education Office, St. Helens.